

STATICAL ESTIMATES

OF THE

MATERIALS OF BREWING;

OR

A Treatise on the APPLICATION and USE of the

SACCHAROMETER;

An INSTRUMENT constructed for the PURPOSES

Of regulating to ADVANTAGE the

OECONOMY OF THE BREWHOUSE;

And of establishing the MEANS of producing

UNIFORM STRENGTH in MALT-LIQUORS;

Including a definite Estimate of the intrinsic Value of different MALTS, the Produce of ENGLISH, SCOTCH, and Foreign BARLEY; the specific Gravities of WORTS, from which several Kinds of ALE and PORTER are made; the ATTENUATION of the DENSITY of fermentable Fluids, by the Action of Fermentation; the Portion of SPIRIT generated by that Action, in Beers of different Lengths; the Mode of estimating the STRENGTH or INEBRIATING QUALITY of fermented Liquors; with some Propositions for effecting a very considerable Saving in the Consumption of MALT.

By J. RICHARDSON. —K—

—Docet "*ratione, modoque.*" HOR.

L O N D O N,

Printed for G. ROBINSON, Pater-noster-row; J. SEWELL, Cornhill; T. BROWNE, at Hull; C. FILLIOTT, at Edinburgh; LYKE WHITE, at Dublin; and T. WHITE, at Cork. 1784.

1. The first part of the document is a letter from the President of the United States to the Congress, dated January 1, 1861. It is a copy of the original, and is signed by the President.

P R E F A C E.

S E V E N years have elapsed since the author of the following sheets addressed himself to the public, on a subject which, if at that time it attracted their notice, will, it is conceived, as now presented to them, be found to have still a greater claim to their attention. His views, on that occasion, were to effect an eventual profit to the brewer, from the melioration of his produce; on the present, they are directed to his actual and immediate advantage, from a reduction in the quantity of the materials he employs.

The favourable reception which attended that address, the success resulting

from the practice it referred to, in the increased and increasing trade of those to whom it was communicated *, and their ingenuous and repeated acknowledgments of the advantages derived from it, have long been matter of pleasing reflection to him.

Incited by this to pursue his investigations, he was determined to persevere till he should be able, if practicable, to rescue from the hands of ignorance and illiterature, the conduct of a business of such magnitude as the brewery of these kingdoms; and to give the features, form, and proportion of science to an object so highly valuable, which has been, for centuries past, disguised by obstinate stupidity, and deformed by the empiricism of ridiculous old women.

* The author still continues to communicate this practice, comprising the several processes of brewing *porter* and *pale malt-liquors*, of every species, the terms of which may be known by applying to him.

How

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How far he has succeeded in that attempt, on the present occasion, must be left to the candour of the impartial reader to determine; and whether the end will ever be entirely accomplished, is matter of doubt. A single glance upon the diversity of habits and sentiments of men in general, will readily suggest obstacles which stand like mountains in the way. New doctrines do not soon become objects of general assent; and the establishment of a formal system where public opinion has long denied the existence of principles, is a work of no ordinary difficulty. The ingenuity of a Harvey first traced the vital current in our veins, but it was unequal to the task of conquering that habitual stupidity which stamped incredibility on the discovery.

The humble origin of the brewing business has long entailed a general concurrent opinion, that its professors need neither genius nor education; and in conformity to that opinion, has this profession,

fection, more, perhaps, than any other, of the like national importance, been disgraced by sinking into the hands of the most ignorant and illiterate; from whose contracted understandings, biased by the influence of strong prejudice, and rendered obstinate by the pride of long practice, the man who offers the adoption of a new system, however clearly supported by reason, has a host of enemies to encounter.

It is, however, a happiness that the extensive connections of modern times have induced

* If the reader be in the humour of smiling at a proof of this observation, he may amuse himself for a moment, with the perusal of the following specimen of the science and literature of a country brewer, in Lincolnshire, copied *verbatim & literatim* from his letter, which the author received in consequence of having put him to the important expence of *four pence*, for the postage of his *Advertisement to the Brewers*, circulated in 1777. It contained the said advertisement inclosed, in order to double the postage, and is not the only epistle of the kind with which the author was amused at that time.

§ A.

(COPY)

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induced men of fortune, education, and

(C O P Y .)

Sr, I know Not who or what you are or what
Profession you are off I have Recd, a long
Roddas mantade about Nothing you have said No-
thing though there is a grate deal in your Paper
you Point me to nothing how I am to avoid
these accidents that may hapen So upon the whole
I looke on it as a pefe of quackens you want to
hum the Contrie at any Rate if you Can but Get
there Cash but I Defie you to Gard against what
you Make Mention off I think My 45 years Ex-
perience is a Match for your *there* Pray Sr, what
would you have thought of me if I had Sent you
Such an apistle about My 45 years Experience
and Say as much upon it as you have dun on
your *there* as not knowing me you would have
thought me A Sawie Imperdent fellow to take
upon me to Dictate to you about your Buissness
Pay you to Charges and order to Post Pay yours
to Me what rite have you to Dow this to me
I say you are a Safe Imperdent fellow whome
Soever you are I thought I Could not Make
you a better Prefant then to send you your own
a gaine, you are Sum Poor Roge or other or yond,
never take Such libertys to rit to People you
know Nothing off

To Mr. John Richardson Jos, Coffee House
Mitre Fleet Street

liberality, in this country at least, to adopt the profession, and render it respectable. To these the author wishes more particularly to address himself, in the expectation that, influenced by their example, others of a less speculative or less comprehensive turn of mind, may be induced to try if they cannot discover some scientific *traits* in the objects of their daily pursuits, and benefit themselves by the discovery.

The introduction of the thermometer into the practice of the brewery, general as it is now becoming, was by slow and cautious steps. The sturdy ignorance of a country fellow, dignified by the appellation of *brewer*, too often opposed itself to the good sense and discernment of his employer, to the defeat of the intended improvement; though it did not always happen that this ignorance was unmixed with *cunning*. There was sometimes an apprehension that the instrument might become a rule in the master's hand, by which

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which the abilities of the servant might be measured; and that the interference of the former might prove destructive of the consequence of the latter.

The prevalent practice of those days (and it is not yet annihilated) was either to mix a given quantity of cold, to a given quantity of boiling water, in the copper, for the purpose of mashing; or to turn the boiling water into the mash-tun, and suffer it to remain till the brewer could *see his face in it*, before the malt was put into it; both of which are sufficiently ridiculous to be discontinued, where the means of measuring heat are to be obtained. As an appendage to this practice, the finger supplied the place of a thermometer, in determining the fermenting heat of the wort, and the brewer was persuaded that the delicacy of his sensations, in that business, precluded the necessity, and rendered impertinent the adoption of a substitute.

Some

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Some of the brewers on the continent carry the matter still further, and determine the heat of the scalding liquor intended for mashing, by the finger also. One of these, to whom the author mentioned the use of the thermometer, in ascertaining the degrees of heat, replied, with a significant nod of the head, attended with a kind of contemptuous smile, *Monsieur, je suis la chaleur de l'eau par le doigt, aussi bien que vous la savez par votre instrument.*

So little, indeed, do the generality of inferior brewers expect matter of science in their business (though they frequently affect great *secrecy*) that their inattention to some circumstances, which force themselves on their notice, is really a state of warfare against common sense.

A gentleman of veracity affirms, that having observed to a brewer of this character, that his under-back was *leaky*, and that he was subject to a daily loss, in the quantity of wort wasted thereby; the
other

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other exclaimed "Not at all! I lose no-
 "thing by the little wort which runs out,"
 "for I always draw my usual length." In
 other words, he made up with water
 what he lost in wort, and so thought
 himself no sufferer. It is much to be
 feared, that upon such an economist, the
 doctrines hereafter inculcated will have
 little influence.

It frequently happens, too, that men of
 plain good sense, from not being accus-
 tomed to think abstrusely, or to turn their
 minds to scientific subjects, do conceive
 most extravagant ideas when a thought
 relative to these matters happens to strike
 their imagination. A very respectable
 person of this description, speaking of the
 gravity of wort, alledged, that the vari-
 ation of that circumstance could be no
 certain foundation for variety of strength
 in the beer; "because, said he, I could
 "add to its gravity by putting salt into it,
 "or I could make a mixture of salt and
 2 " water

“water of the same gravity, and yet the
“wort with the salt in it would not be
“productive of an increase of spirit pro-
“portioned to its increased gravity, and
“the salt and water would produce none.”

In the same manner it might be insisted, that the superior lightness of a spirituous fluid is no proof of superior strength, because it is in the power of a person to dulcify the strongest spirit, till it is as heavy as the weakest, that it may elude the detection of every statical apparatus.

On the other hand, there are those who, from a conviction of the inefficacy of the common modes of estimating the value of malt, are induced to rack their invention with the view of arriving at a more certain determination, though the means they adopt often prove as inadequate as those they have rejected. Amongst these may be reckoned the attempt of an old gentleman in the north-west of England, who, after having mash-

ed

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ed a small quantity of malt in a tea-pot, held a grand convocation, consisting of himself, his wife, and his most experienced servants, who in due form sat in judgment upon its merits, which were to be determined by the evidence of the palate, in tasting the wort; when, after due discussion, the decision of the majority was agreed to be final, and the malt was valued accordingly. This curious circumstance the old gentleman related, with great good humour, on seeing the author's apparatus hereafter described, thereby intimating a just sense of the want of such certain means of discriminating the value of the materials, and a ready docility to adopt them whenever they should be obtainable.

The darkness in which the business of brewing is involved, extends even to the legislature itself, as is evinced by the frequent disputes between brewers and officers of excise, on the subject of distinguish-

ing worts chargeable with the strong-beer duty, from those which are to be charged only as small; and this seems to have occasioned the late act of parliament for making a separate and advanced charge upon *table beer*, to be compulsory upon the brewer to *brew it alone*; that the officer may not be puzzled in applying his only means of discrimination, consisting in dipping his finger into the wort, tasting it, &c. and from these instances it may be perceived, that the finger is or has been a very important agent both to the brewer and the revenue officer, in the exercise of their different functions. In this ignorance, also, originate those ridiculous restrictions which prohibit the mixing of small with strong beer, in order to accommodate the palate of any person with the liquor he prefers. Were the duties charged according to the specific gravity of the wort, these altercations would immediately vanish, the revenue would be increased, the brewer would
be

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he at liberty to make, alter, or compound his liquor into as many and as various sorts, as he has palates to please, without subjecting himself to the interference of the officer, or the lash of the law,

As it is not, however, the business of the author to prescribe legislative regulations, he has only to assert, that from a long experience of the utility, and beneficial efficacy of the instrument hereby offered to the attention of the public, he has the clearest conviction of the accuracy with which it accomplishes the purpose intended by the whimsical essay above quoted, and of the great advantages derivable to the brewery from its general adoption, even were its ordinary application, only, as directed and explained in the treatise, to be the object of that adoption; but should the extraordinary practice discovered in the course of his experiments, and proposed, in the *postscript*, to be particularly communicated, become also an universal practice with every brew-

er,

er, the event, exclusive of the former consideration, must be a considerable reduction in the general price of the materials, as well as a particular saving to individuals, in the quantity consumed.

To particularise its effects on the price of malt, only, as the article from which the greatest advantage is to be derived, it needs only to be considered, that if the most moderate computation of the average saving, resulting from the extraordinary practice above alluded to, be *five per cent* in the general consumption, the event of that diminution would be equivalent to an increase in the natural product of the earth to that amount; for if the then annual consumption of malt be signified by 95, and there be 100 brought to market, the supply exceeding the demand, in that proportion, must of necessity produce a proportionate reduction in the price. Hence a double advantage would accrue to the brewer; first, from the general event, which lessens the price; and then

then from his particular saving in quantity, calculated at the reduced rate.

Let us suppose, for the sake of stating the matter clearly, that a person brews at one time thirty quarters of malt, for which, as things are now circumstanced, he pays 40 shillings per quarter, making the whole cost 60 pounds. Let us then suppose the improvement alluded to, has taken place generally, so as to have reduced the price in a ratio of two shillings per quarter; in which case the same person, adopting the improved practice, and brewing the same quantity of liquor, of the same specific strength, would find himself thus advantageously situated.

Instead of 30 quarters of malt, which at 40 s. per quarter would cost — £ 60 0 0

Deducting the five per cent saving,
he would only use $28\frac{1}{2}$ quarters at 38 s. £ 54 3 0

Whence the difference in favour of the above practice is — — — £ 5 17 0

This, at first sight, appears a clear gain of 10 per cent; but, on a further examination, it will be found to exceed that proportion.

If we suppose the present annual consumption of such a brewer to be 3000 quarters of malt, and that its cost is £6000; then making a deduction from the quantity of 150 quarters, for the supposed saving of five per cent, and of 2 s. per quarter from the price, for the supposed general reduction, in consequence of a general adoption of the practice recommended, the simple advantage attainable thereby, in this instance, may be thus calculated :

State of the present practice.

Capital required for 3000 quarters of malt, at 40 s.	— — —	£ 6000 0 0
One year's interest on the same	—	230 0 0
Total		£ 6300 0 0

State of the proposed improvement.

Capital required for 2850 quarters of malt, at 38 s. five per cent being deducted from the quantity and price, as above estimated	— —	£ 5415 0 0
One year's interest on the same	—	270 15 0
Total		£ 5685 15 0
Annual saving by this plan	— —	614 5 0
		£ 6300 0 0
		Hence

Hence it is evident that there would be a net *additional* profit of near *eleven per cent* on the £ 5415 advanced, besides the convenience of making that sum supply the place of £ 6000, effecting thereby a reduction of capital to the amount of near ten per cent; which is an object of no small importance, where money is not abundant.

As the probable means of universal benefit, this subject seems to claim universal attention; and as there are particular situations and circumstances in which the ratio of advantage may be as three to two, and in some cases it may be double, its consideration ought to be proportionally incentive to individuals, to the obtaining the proposed end, where there is a probability of such circumstances existing.

These observations, united to the particular elucidation of the advantages derivable from a continued use of the Saccharometer, which is the subject-matter

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These observations, united to the particular elucidation of the advantages derivable from a continued use of the Saccharometer, which is the subject-matter

of the ensuing sheets, will, it is presumed, be a sufficient inducement to the liberal, the candid, and even the wary, to commence a satisfactory enquiry on the occasion, in the prosecution of which there is every thing to hope, and nothing to risque.

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STATICAL ESTIMATES

OF THE

MATERIALS OF BREWING.

INTRODUCTION.

*Containing the Description and Use of the
Apparatus necessary for conducting the
Experiments.*

I. The SACCHAROMETER, its construction and principles.

THAT the basis of this instrument
may not appear hypothetical, nor
its application be deemed the result of closet
speculation, to be trusted with caution by
the man of business, a recital of the mode
of its construction may be satisfactory, to
convince the timorous that in its adoption

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he treads on sure ground, and to confirm the adventurous in the idea that the advantages promised by the use of it, are founded on the substantial proofs of actual practice.

Having procured an instrument to be made, according to particular instructions, we adjusted the weight (*a*) at the bottom, (*see the plate, fig. 1.*) so as to occasion the instrument to sink, in the heaviest water we could procure, till the whole was immersed except the upper part of the scale, which was intended to be graduated downward from that part where the surface of the water reached (*b*), and which was marked for that purpose. We then put the instrument into distilled water, and it sunk to the bottom; but the stem being a tube, exactly fitted by the part to which the bottom weight was screwed, and which was shut up, on the first immersion of the instrument, we drew this part a little way out of the tube (*c*), by which the bulk of the instrument was increased without adding to its weight, and, by a little adjusting, it then sunk no lower in

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in the distilled water, than it had sunk in the heavy water first made use of. The sliding part, of course, then became a *regulator*, by the drawing out or shutting up of which, the instrument might be made a counterpoise to any water fit for domestic use. This being noted, we pressed the regulator into the tube so far as that the instrument sunk to the point (*b*), before indicated, in the river-water we employed for brewing, and thence becoming the equipoise or representative of that water, it was ready for our experiments.

It is here to be noted, that the water, in which the instrument was immersed, was always at fifty degrees of heat, by Farenheit's thermometer; and having adopted this temperature, as more stationary and more practicable than any other, we are altogether to be understood as referring to, or implying it, except where the contrary is expressly mentioned.

Our next care was to provide a half barrel, as exact in its guage as we could

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procure, which having filled with our river water, we weighed it as accurately as the weights we were necessitated to employ would admit of; and having deducted the weight of the cask, we found that of the water to be $184\frac{1}{2}$ pounds, or 369 pounds per barrel, of 36 gallons beer measure. We then filled the same cask with our first wort, previously cooled, and found the net weight to be 204 pounds, or 408 pounds per barrel, making an addition of 39 pounds to the weight of the water; which experiments being repeated in different worts, from each of which specimens were saved, we proceeded to apply the instrument.

Having immersed it in the first wort, we fixed an additional weight to the top (a) of the scale, which weight being adjusted till the instrument sunk in the wort to the extreme point (b) of the intended graduation, the additional weight immediately became the representative of the 39 pounds additional density, acquired or extracted by

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by the water from the malt, in the same manner as the instrument itself was, before, the representative of the simple element; whilst the combination of the instrument, and its additional weight, represented the wort itself, consisting of water and a quantity of extracted fermentable matter equal to 39 pounds per barrel.

A second wort, weighed in the same manner, producing an addition of 21 pounds per barrel, we adjusted likewise a weight for it, which weight was then the representative of that addition. Having thus obtained the two weights 39 and 21, we weighed them separately, and reducing the amount of each into grains, we found they had a correspondent relation to each other; and, of course, that a weight equal to the sum of them both, would be the exact representative of 60 pounds per barrel acquired density, at the same time that another of half that sum would represent 30. A confirmation of this was immediately obtained, by forming the weight 30,

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according to this rule; and then mixing equal parts of the two worts together, the instrument, on being immersed therein with that weight at the top, sunk down to the point before indicated. In the same manner 29 parts of this wort, and one of water, being mixed together, and a weight being formed equal to 29 parts of the 30, contained in the weight 30, the weight so formed was fixed upon the instrument when immersed in the said mixture, and it sunk down as before, confirming thereby the truth of both, and establishing a double security for the accuracy of the experiments to be made with an instrument constructed upon these simple principles.

In order to indicate the intermediate degrees, or parts of a pound, we immersed the instrument in the wort or mixture of 30 pounds per barrel, when the weight 29 only was applied, and pressing it down to the usual point (*b*), the finger was taken away, and the instrument immediately emerged or rose up, till the bulb was but
just

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just covered with the liquor, the surface of which being then near the bottom of the scale (*e*), a mark was made at that point, and the space between that and the upper point (*b*), being divided into ten equal parts, those graduations were then so many one-tenth parts of a pound, because the whole space was equal thereto; for the weight 30 being applied, the instrument again sunk to the upper point as before.

The penetrating eye of critical philosophy will here readily perceive that this, though a broad and strong foundation, every way adequate to the firm, rough structure which the hand of business is to build upon it, is by far too rude a basis for the finished edifice, which philosophical investigation might be inclined to erect thereon. Like stone, rough for the quarry, our unwieldy materials, though well enough adapted to the brewhouse, were to undergo the operation of the chissel and square before they could be admitted as

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the components of a building whose bulk and proportion were to claim the attention of the public. The guage of our cask could not be relied on as the accurate ad-measurement of its contents; nor, in the situation where the first foundation of our system was laid, was it in our power to procure any vessel whose capacity was so truly ascertained, as to give with greater precision the contents of a barrel, upon which, as a measure universally applicable to the business of the brewery, it was thought proper to form our calculations. As much, too, might be said of our rude half-hundred, quarter of a hundred, and other weights, for whose correctness we had no better authority than that of the founder who cast them. On these experiments, however, our first instrument was formed, and we are happy to find that it varied very little from that accuracy with which those now offered to the public are made; the principles of which are formed on the nicest philosophical calculations and experiments, for which

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which we are indebted to the obliging offices of a friend, whose situation enabled him to procure such means of conducting them as we could not have obtained; and whose judgment in applying them was, we were conscious, superior to any capability we could have called into action on the occasion. His manner of investigating the principles, and calculating the construction of the Saccharometer, as communicated by letter, contains so many judicious remarks, and displays so much ingenuity, that we are induced to subjoin the whole, by way of appendix, as a very probable gratification to the scientific reader, severely as it reflects on the *rudeness of our guage and weights*, to which, however, we have not been so much attached as to refuse the adoption of a more accurate system.

II. ASSAY JARS.

THESE need be nothing more than small tin vessels, (*see plate, fig. 2.*) of
about

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about eight inches long, and two in diameter, with a small ear or handle at the top, somewhat like that of a common tin pot (*a*). There may be six in number, in order to keep, till the brewing is finished, specimens of each wort, before and after boiling, if curiosity or any other motive should induce. Three of them, for the three unboiled worts, should have lids or covers (*b*), the circle or rim of which must fit within the top of the jar, and not slip over it on the outside. The use of this is to prevent the loss of any of those aqueous particles, which will necessarily evaporate at first; but being arrested and condensed by the lid, immediately trickle down the side, and by that means are again conveyed into the wort from which they arose; whereas, if the lid slipped upon the outside of the jar, a great part of the condensed vapour would find its way between the inside of the rim of the lid, and the outside of the jar, and so be lost.

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III. J A R C A S E. VI

A box 16 inches long, 12 inches broad, and 7 deep, on the out side, will be sufficient for six jars. It should be lined with milled lead, in order to hold water; and through the lid, which may be nailed fast down, should be made six circular holes, about $2\frac{1}{2}$ inches diameter, in order to receive the six jars. (*See plate, fig. 3.*) These may be made three in a row, at equal distances from each other, and from the ends and sides of the box. A small lip or spout should be made from the upper part of the lead-lining, in order that the water may be the more readily poured out thereby; and that it may run over in that place only, in case of the box being accidentally filled too full. When intended for use, it is to be filled so full of cold water as just to admit the immersion of the six jars without running over.

IV.

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IV. REFRIGERATOR.

THIS instrument may be made of tin, and being intended to contain no more than the quantity of an assay-jar full, its dimensions may be nine inches deep, and its breadth seven inches one way, and half an inch the other, forming a broad and flat or thin vessel, resembling a tin case sometimes made use of for the preservation of deeds or other writings. (*See plate, fig. 4.*) The reason of its being made thus thin, is, that when charged with hot wort, and plunged into cold water, the effect of the cold may be almost instantaneous, which is nearly the case; for the quantity of wort being less than a pint, and the surface brought into contact with the cold water (the intervention of the tin only excepted) containing very near 140 square inches, it may easily be conceived how rapidly the heat must be dissipated.

The

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The upper part should have a lip (*a*) for the more conveniently pouring out the wort, and on the opposite side should be a socket, to which a handle (*b*) should be soldered. The use of the socket is to receive a stick, of any convenient length (*c*), which is to fix in the socket by a pin, in the same manner as a bayonet is fixed; by which means it may be fastened in, when the refrigerator is to be dipped into the copper, and taken out, as an incumbrance, when it is charged with wort. It is to have two lids or covers, (*d* and *e*) the rims of which are to slip within the edge of the vessel, as is recommended for those of the assay-jars. One of the covers is to be perforated full of small holes, in order to admit the wort, and at the same time to prevent the hops from entering; the other is to be whole, and is intended to supply the place of the first, the moment it is taken out of the copper.

The length of the stick, inserted in the socket, is entirely to be determined by
cir-

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circumstances, it being intended only as the means of holding the refrigerator in the wort, till it is filled, without endangering the hand from the steam.

It should have a broad flat bottom (*f*), in order to enable it to stand upright, otherwise there would be a necessity of supporting it in that position.

STATICAL

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OR, A

TREATISE

ON THE

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PART I.

Containing the Principles and Theory.

BEFORE we enter into a particular discussion of the utility of the Saccharometer, or attempt to direct its application, we shall endeavour to explain and familiarize such few philosophical and technical terms, and such natural and chemical

chemical operations, as unavoidably occur in the elucidation of a subject in which both nature and art are busy agents. Those to whom these subjects are already familiar, will, we doubt not, have candour enough to bear with patience the recital of matters so well known to them, when they reflect that our intention is only to convey to those who know them not, such information thereon as may facilitate and render effectual the application of the instrument hereby offered to their attention and practice.

SECTION I.

Of DENSITY and GRAVITY.

THE term *density* is applied to all bodies, whether solid or fluid, in order to convey an idea of their weight, in relation to their bulk; so that any body is said to be more or less dense than another, when it contains more or less weight in the same bulk. Thus a cubical inch of standard silver being ten times
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the weight of a cubical inch of rain-water; is said to have ten times the density of that fluid. The discovery of this principle, as related to the doctrine of gravitation, and the laws of gravity, has been of infinite use to science in general, and to mechanics in particular. That commerce and the domestic arts have not been unbenefited hereby may be evinced by its daily utility to the merchant and manufacturer, though that utility is unfortunately less beneficial than it might be, were the former more frequently to let commercial speculation embrace scientific, and the latter more generally to bid theory and practice walk hand in hand. There is not, perhaps, an article subject to the pursuit of commerce, whose value is not, mediately or immediately, determinable by its gravity; and it will readily be perceived, that the materials of the manufacturer, having once been the commodities of the merchant, have their value ascertainable by similar means. The gold-

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smith and lapidary can bear testimony to the importance of this discovery in discriminating the value of those rare articles which occupy their attention; and that objects of inferior worth are not made the subjects of a like investigation, arises from that inattention to things of daily occurrence, which seems to imply so perfect a knowledge of their qualities, in every respect, as to preclude the necessity and propriety of all scrutiny. Hence, to apply the subject to our immediate purpose, whilst the brewer is adjusting his balance to scrutinize the demerits of a sweated guinea, his servant, perhaps, in the execution of his unscrutinized orders in the brewery, is wasting to the amount of several. That this arises from a want of information in the doctrine which is our present subject, will, we doubt not, be sufficiently evinced in the course of these pages. The farmer well knows that wheat of 70 pounds per bushel will produce, in a certain proportion, more flour than that

that of 60, because he can apply his scales to the wheat before it is ground, and to the flour when dressed. The brewer, in like manner, can tell that barley of 56 pounds per bushel will make better malt than that of 50, *ceteris paribus*; but when he comes to infuse it in water, he has no criterion to direct his judgment; his rule of proportion is drowned in the fluid, and he is necessitated to rest upon the vague determination of the palate, what we shall hereafter prove to be discriminable, to the greatest philosophical precision.

And this naturally leads us to the consideration of *gravity*, or that tendency which all bodies of greater density than the atmosphere have towards the centre of the earth; and as this tendency increases in proportion to the greater density of any body, the difference in this tendency, or, in other words, the different density of different bodies, compared with each other, is termed *specific gravity*.

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gravity; by the application of which term we are enabled to convey our ideas on the subject of the density of all bodies, whether solid or fluid, previously fixing upon some body, of the least variable nature, as a standard of comparison. Hence, making rain-water the standard, and calling it 1000, philosophers have communicated to us the density of every body which has been the subject of their enquiries. Thus the density of pure gold, or rather its specific gravity, is said to be 19640, that of fine silver 11091, that of lead 11325, &c. &c. intimating, by the proportion which these numbers bear to 1000, that gold is near twenty times, and that silver and lead are more than eleven times heavier, or more dense, than rain-water.

Our means of ascertaining, with accuracy, the value of the materials employed in brewing, through all those modifications in which the various parts of the process offer it to our notice, are
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somewhat similar to those which have been ineffectually, because inadequately, employed by others; the instrument itself, though differing in principle, assuming the general form of an *hydrometer*, by which the specific gravity of fluids is generally determined; but it is rather from the application than the form of the instrument, that the value of the information we are about to communicate is to be estimated.

The fluid which is the subject of our investigation, is, in the first instance, *water*, being the menstruum employed for the purpose of dissolving and extracting the saccharum and other valuable qualities of malt; which compound liquor, after extraction, receives the denomination of *raw wort*, and in that, its second state, demands a very attentive examination. The third predicament in which we find it claiming our attention, is in the state of *boiled wort*, being then more dense by decoction, and more heterogeneous

rogeous by the addition of the essential qualities of hops, extracted during that operation. The fourth state of our fluid is that when, by a previous fermentation perfectly finished, it becomes a more uniform, more homogeneous, and completely vinous liquor, generally termed *beer*, or *malt liquor*; which is the genus, of which *porter*, *amber*, *ale*, and *beer* (the latter particularly so termed, whether *small* or *strong*), are but so many species or distinctions, again subdistinguished by the addition of the places most celebrated for their respective production; as *London porter*, *Burton ale*, *Dorchester beer*, &c. In the general practice of the brewery the three former are all the situations in which there is a positive necessity for the application of the saccharometer; the fourth being only of relative utility, having regard to the strength or degree of spirituousity generated by the action of fermentation, the discovery of which has long been wished for by those interested

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in the production of malt liquor. And this leads us to a fifth application of the saccharometer upon our fluid in its purest and most homogeneous state; viz. when, by a final exposure to heat in the alembic, it becomes a condensed vapour, and is dignified by the appellation of *spirit*. For this purpose an additional set of weights would be requisite, when, by embracing the business of the distiller, fresh objects of pursuit, and fresh sources of utility would present themselves, but not unattended by additional difficulties in directing its farther application.

That the use of this instrument bids fairest to accomplish the desirable end of ascertaining the strength of malt liquors, will hereafter appear; and that this end has not yet been accomplished is not to be wondered at, since the very mode of producing them in perfection, common and familiar as it appears in the eye of the public, is in general but little understood*.

* See *Theoretic Hints on Brewing*.

The only attempt, or rather *profession*, to ascertain their strength, within our knowledge, was that of a late celebrated philosopher, who, on publishing an hydrometer for assaying spirituous liquors, roundly asserted in his treatise on that subject, that it was "equally useful in the discovery of the strength of domestic liquors, such as beer, ale, punch," &c. &c. These are his words, to the best of our recollection, as we quote by memory. Unfortunately, however, for the credit of his assertion, after we had tried various sorts of malt-liquor by it, and found their specific gravities equally various and disproportioned to their evident though undefined strength, we applied to him for information on the method of using his instrument in order to attain these ends, when he ingenuously signed his recantation, in reply, by acknowledging that "he knew of no instrument which would discover the strength of malt-liquors." Being convinced, notwithstanding, that this discovery must be involved

involved in the doctrine of gravity, and puzzled to find the density of small beer equal or very little inferior to that of strong, whilst the densities of different sorts of beer exhibited a perfect chaos of incongruity, it was not till after the clearest conviction, from much experience, of the very great utility derivable to the brewery from the application of an hydrostatical instrument, that we formed the plan of the *Saccharometer*, and adapted the principles of it to every practicable part of the brewing process, thence attaining the grand end of our enquiries, viz. *To trace the progress of vinous SPIRIT, from its first foundation or embryo, in the saccharine and other fermentable parts of the producing fluid, to its final issue, in a state of perfection, from the still.*

The theory of this process is as follows: the menstruum or water, employed by the brewer, becomes heavier or more dense by the addition of such parts of the materials as have been dissolved or extracted by,
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and thence incorporated with it; the operation of *boiling*, and its subsequent *cooling*, still adds to the density of it, by *evaporation* (as will be hereafter explained), so that when it is submitted to the action of fermentation, it is more dense than at any other period.

In passing through this operation of nature the extraordinary power of which, in changing the form of matter, can only be shewn by its effects, as the mode of action in the production of that change must ever be unknown to us, we find that the fluid we are here speaking of, no sooner begins to ferment than its density begins to diminish; and as the fermentation is more or less perfect, the fermentable matter, whose accession we have traced by the increase of density, becomes more or less attenuated, and in lieu of every particle thus attenuated, a spirituous particle, of less density than water, is produced; so that when the liquor is again in a state of quiescence, it is so much specifically lighter than

than it was before, as the action of fermentation has been capable of attenuating the component parts of its acquired density; and, indeed, were it practicable to attenuate the whole, the liquor would become lighter or less dense than water; because the quantity of spirit produced from and occupying the place of the fermentable matter, would diminish the density of the water in a degree bearing some proportion to that in which the latter had increased it.

Hence it is evident that the strength of fermented liquors cannot be ascertained by the common doctrine of specific gravities, or a comparison of their density with that of the simple element employed in their production; but by a particular application of relative or comparative gravity, if it may be so termed; whence this general axiom may be established as a principle, viz. *That the attenuation of a given weight of fermentable matter, in any fluid, will produce a certain quantity of spirit,*

spirit, and that equal quantities of attenuated matter, in all fluids, whether of equal or different densities, will produce equal quantities of spirit, without any regard to the proportion which such attenuation may bear to the density of either. The inference is obviously this: if the specific gravity of the fluid be noted immediately before fermentation, and again at any time after, when the operation has entirely ceased, the difference between the former and the latter will indicate the weight of fermentable matter attenuated, and, of course, the quantity of spirit produced. That this is approximating very nearly to the discovery of what is termed *strength*, in fermented liquors, will not, we presume, be disputed, but that it is not entirely competent to the end proposed, will be shewn in its proper place.

From what has been said on this subject, it will readily be collected, that the great use of the saccharometer depends on noting the different density of any fluid
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in the different states wherein it may be found; or, in other words, the applying it, by the brewer, for the discovery of the specific gravity of every wort, in order to determine what portion of the materials each has imbibed; thence to calculate an aggregate of the whole; and from a division of that aggregate into given portions, to effect an uniform regulation in the product; thereby reaping every advantage attainable from perfection of materials, or excellence of process, and avoiding every inconvenient effect resulting from contrary causes.

The doctrine of the saccharometer, employed in this discovery, is founded on the well-known theorem, that when a solid body is floating in any fluid, the part of the fluid displaced by it is equal in bulk to so much of the solid body as is immersed in it, and equal in weight to the whole of that body. On this principle, the instrument, being immersed in water, should sink to a given point upon
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the scale (as indicated before), and there remain stationary; but as the specific gravity of water is not every where the same, the invention of the *regulator* has rendered the instrument correctly applicable to every variety of water; for by drawing it outwards or pressing it inwards, till the instrument sinks to the required point in the water intended to be made use of, it then becomes the exact representative of that water, and is fit for immediate application.

The instrument being so adjusted, the water is then the true standard of comparison for our experiments; and if, on being immersed in wort, it refuses to sink to the same point to which it descended in water, we are certain that the former is more dense than the latter, by the resistance it makes to the descending instrument; and that if a weight added to the top of the scale causes it to sink to the point intended, the weight so added must be the representative

representative of the specific gravity of the wort, or of the addition made to the density of the water by the accession of fermentable matter, as has been before intimated; for that part of the fluid displaced by the instrument is still the same in bulk, but of greater density, because the part of the instrument immersed is of the same magnitude, though the instrument itself is increased in weight, agreeably to the theorem just quoted. To ascertain this weight, so as to give it an immediate relative application to known quantities of wort, is essential to the advantageous use of the instrument, an illustration of which has already been given in treating of its construction.

In applying it to ascertain the strength of a spirituous fluid, the essence or final state of perfection of all fermentable liquors, a new standard is to be sought for; and though the means of applying it are similar to those just mentioned, the end or inference is diametrically opposite;

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for in the former instance increased density is additional value, whereas in the present case, specific lightness, or rarity, is intrinsic worth; the one deriving its excellence from extraction, or the uniting to itself the essence of soluble bodies, the other from sublimation (if the term may be allowed) or the withdrawing itself pure, and, till condensed, in an impalpable form, from the invelloping medium which was the bond of its union with the remaining parts of the fermented liquor which gave it existence.

As in the first process the lightest state of the fluid necessarily becomes a standard, the same rule is to be observed in this; nevertheless the standard for the latter is not so easily established as that of the former; because the governing fluid of the first is common to all the world, whilst that of the last is only obtainable by the nicest chemical process; and when obtained is vague and indefinite. The fluid here alluded to is *alcohol*, a spirit so
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highly rectified, and so perfectly dephlegmated as to be totally *inflammable*; one criterion of which is, that having gunpowder put into it, and being then set on fire, it will so perfectly consume itself as at last to fire the gunpowder, which it could not do were the least particle of aqueous moisture to remain in it. But as this state of total inflammability may have various degrees of perfection, and as two quantities of alcohol may be different in purity, and yet may be both capable of firing gunpowder, or of standing the test of other criterions, this standard must be, in some degree, indefinite, till a more perfect mode of ascertaining its purity shall be discovered. In general, however, it means the purest product of the most perfect distillation, or the lightest palpable fluid which can be produced. Hence alcohol is made the standard of purity on one hand, water the boundary of impurity on the other, and the medium or a commixture of equal parts of both is termed *proof spirit*. This commixture, therefore, as a state in which

all spirits are most applicable to domestic purposes, is ever made the measure by which their value is estimated; so that if any spirituous liquor be lighter or stronger than this medium, it is termed *above proof*; if weaker, *below proof*; and their relative estimates are determined by the abounding portion of alcohol in the one, and by its deficiency, or the abounding portion of water in the other. Thus spirits are said to be *one to three*, *four*, or *five*, or so many *per cent*, *over proof*; or, on the contrary, *under proof* in a like definite proportion: meaning, by the former, that it would require one gallon of water to be added to so many gallons of the spirit so estimated, or so many gallons of water to one hundred of spirit, to bring it to the standard of *proof spirit*. By the latter, or the same modes of expression applied to *under proof*, it is meant that the water is abundant in those several proportions, and that it would, of course, require such quantities of alcohol to be added, in order to raise it to the point of

proof spirit aforementioned ; in both cases making due allowance for the concentration* of the commixture.

In assaying these fluids, being of less specific gravity than water, it would be necessary that the saccharometer should be reduced in weight, (which is effected by changing the weight at the bottom) so as to be the exact counterpoise of alcohol, when immersed therein, as it was that of water before the alteration. In this case it would be ready, with the addition of requisite weights for the top, as before mentioned, to investigate and ascertain,

* By *concentration* is meant that principle, in the commixture of two fluids of such different gravities, as water and alcohol, by which the particles of the one commix or fit so closely with those of the other, as to occupy a less space when united than they did separate. For instance, 50 gallons of water and 50 gallons of alcohol, when mixed together, do so far blend, incorporate, or *concentrate*, that the whole commixture will fall considerably short of 100 gallons ; and of course the number of gallons of water or spirit, to be added to bring the fluid to proof spirit, will vary in that proportion.

with the greatest accuracy, every degree of impurity existing in any spirituous fluid, by the simple comparison of its specific gravity with that of water. For if the instrument itself, immersed to the required point, be then the representative of alcohol, and the additional weight at the top, which sinks it to the same point in water, be termed 100, and that weight be divided into 100 parts, it necessarily follows that 50, or the one half of that weight, will be the representative of proof spirit; and that one, or a single division, will indicate to the one-hundredth, whilst the ten intermediate graduations on the scale, will shew to so small a degree as the one-thousandth part, the quantity of water contained in the fluid.

To attain, however, that accuracy of which an instrument thus constructed is capable, it would be necessary to attend to a particular which seems hitherto to have escaped the notice of those who have offered hydrometers to the public; and this is to ascertain the extreme point

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of comparison, or the specific gravity of the water intended to form that point, with the greatest possible precision. In an *unmixed spirit*, the intermediate weights should be subdivisions of that which would immerse the instrument in distilled water; but these will not answer the intention if the spirit has been mixed with common water; for, in that case, the extreme point of comparison, opposed to alcohol, being changed, the weights would be no longer proportional parts of that standard, and every experiment made therewith must be inaccurate.

To conduct these experiments with the required precision, we are to take particular care that the heat of the fluid be always the same, at the time of applying the instrument, or that such allowances be made, as experience shall authorize to be equivalent to those effects which heat is known to produce in all bodies, ever expanding them in proportion to its own force and their susceptibility of it; so that

the density of the same body is not the same in a warm as it is in a cold situation, but varies accordingly as the heat varies to which it is exposed; and without including the consideration of these effects in the doctrine of density, all our experiments relative thereto, and all our inferences drawn therefrom, would be erroneous and fallacious, as will be more fully indicated in the following section.

SECTION II.

Of EXPANSION and CONTRACTION.

IT is a well known axiom that all bodies *expand* with heat, and *contract* with cold; or that a body of a certain bulk, at a certain degree of heat, will be increased in magnitude in a greater heat, and be diminished in a less. In solid bodies this principle generally receives the denomination of *expansion* in the former instance, and of *contraction* in the latter; but in fluids these terms are, with great propriety, changed into *rarefaction*

rarefaction and *condensation*; because in the first case the fluid is rendered more *rare*, or of less specific gravity, and in the last it becomes more *dense*, or of greater gravity, than it was in the state which is made the point of comparison. But as these terms relate rather to the quality or consistence of the fluid than to the volume of it, we shall adopt the former on the present occasion, as more applicable to our purpose.

Dr. Halley, it is said, found that boiling water expanded one twenty-sixth part of its former bulk, though in a moderate heat its expansion was imperceptible; and by the same authority we are told that spirit of wine expands one twelfth part of its bulk, at that degree of heat at which it boils; the obvious inference is, that the lighter the fluid the greater the expansion at the same degree of heat; and in the two fluids here quoted the difference is very great, since it is to be considered that

spirit of wine boils at 176, by Farenheit's thermometer, and water at 212.

For the purpose of establishing our system on a firm basis, not of contending with so great an authority, nor of wandering in fields of philosophy unwarranted by an attention to our own pursuits, we were necessitated to enter upon an examination of the expansion of the same simple fluid which forms the subject of one of the doctor's experiments, and which we found to be so correspondent that at 200 degrees it had expanded 3.5 per cent, or near one twenty-eighth part; but the ebullition then became too violent to make an accurate observation at any higher degree. It is with the utmost deference, also, that from observations on our own experiments we are led to enquire, by what means the expansion of a fluid could be accurately ascertained in a state of ebullition, when every part is in evident and violent motion, as well as in a state of copious evaporation? and how the above doctrine came

came to be established, "that the lightest fluids are susceptible of the greatest expansion?" Our own experiments unfortunately tend to confirm us in a contrary opinion; but as we are solicitous that this opinion should not be deemed to owe its existence to hypothesis, we will attempt to describe the manner of conducting those experiments on which it is founded.

Having procured a glass tube of one inch diameter (*a*), and thirteen inches long, (*see plate, fig. 5.*) we caused it to be inserted, by means of an external socket, in the centre of the convex top of a cylindrical tin vessel (*b*), capable of containing somewhat less than ten times the quantity which was contained in a depth of ten inches of the tube. The reason of its containing *somewhat less* than ten times the quantity of ten inches in the tube, was, that being charged with that quantity of water, it might rise up a little way into the tube itself; so that fixing a scale of ten inches,

inches, subdivided into tenths, to the tube, and commencing the graduation at the surface of the water, the length of the whole scale then became the exact measure of the one-tenth part of the water in the vessel, whilst every inch indicated the one-hundredth, and every tenth the one-thousandth part of it; a degree of accuracy beyond which we thought it unnecessary to proceed. In another part of the cover we inserted and supported a thermometer (*c*), the bulb of which went sufficiently deep into the vessel, to indicate the heat of the fluid it contained; and the scale was fixed parallel to the tube and scale of the vessel, that observations might conveniently be made on them both at the same instant. The machine being thus prepared, it became, in some measure, a thermometer within a thermometer; for as the heat of the fire on which it was placed, acted upon the fluid in which the bulb of the thermometer was immersed, the expansion of the fluid in the one, and of the mercury in the other,

other, took place at the same time ; and, of course, the former ascended in the tube of the machine, in proportion as the latter rose in that of the thermometer. By this means we have been able to ascertain the expansion of water, and that of worts of every probable density, and at every practicable degree of heat ; whence we find, in direct opposition to the above-quoted authority, that the expansion of worts (whatever may be the effect of less heterogeneous fluids) increases as they increase in density, and that very nearly in the ratio of their specific gravities ; for, in a prepared wort (stronger perhaps than any ever extracted from malt only) whose specific gravity compared with water, was nearly as 7 to 6, the expansion was as 3.9 to 3.5 per cent, and our experiments made on several worts of intermediate densities were entirely correspondent, as will appear from the *Table of Expansion* given with the saccharometer.

In the application of this doctrine to our worts, which from the commencement to
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the conclusion of the brewing process, and consequently in every point of observation, are in a state of heat various but always superior to that which has necessarily been established as a standard for the instrument, we are immediately led to enquire, what will be the variation in the volume of a wort of any given gravity and quantity, at different degrees of heat, when contracted by that degree of comparative cold which we call the standard temperature?

It is also necessary for us to determine, under the same variation of circumstances, what is the sum of the acquired density of, or the quantity of fermentable matter incorporated with, every extract; but the instrument with its weights, being only capable of indicating the gravity of a fluid at a certain fixed degree of heat, it follows of course that an experiment made with it at any other degree, does only exhibit the gravity of that fluid at that particular degree of heat, and not what it would be at

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the temperature of the standard. Whence the *table of heat*, attending the instrument, is indispensably necessary, to reduce every probable gravity at every practicable degree of heat, to the desired standard, in order to shew the true specific gravity of every extract; and the *table of expansion* becomes equally necessary, to point out, in the same gravities and degrees of heat, the exact volume or *quantity* of the fluid when contracted to the same standard; by the assistance of which we are enabled to ascertain the sum or aggregate of the acquired density, or the amount of the fermentable matter extracted. To exemplify this, we will suppose the instrument shewed the specific gravity of a fluid to be 50, at 100 degrees of heat, and that the same fluid, at 30 degrees, was found by the same instrument to be 53, which is really the case, a calculation founded on the former experiment, without regard to the latter, would be erroneous in a ratio of 6 per cent. Again, if a proper attention has been paid

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to the above circumstance, and we suppose 53 to be the true specific gravity of a certain portion of wort, the whole quantity of which is 100 times that portion, gauged when at 150 degrees, which is a probable heat; without reference to the *table of expansion*, we should immediately multiply 53 by 100, calling 5300 the aggregate density, or amount of the fermentable matter of the whole wort, thereby causing an error of near two per cent; for, by the table just mentioned, it appears that 100 of a fluid of this density, at 150 degrees of heat, are in fact not much more than 98 at 50 degrees; whence the aggregate error, in this case, would be as 5194 is to 5300, or the valuation of the wort would be false to the amount of 106 parts in 5300. And, as the examples we are now giving allude to the experiments on the newly-drawn extracts in the under back, upon the correctness of which the certain regulation of the *length* depends, it behoves us to be particularly careful not to draw

draw inferences from false premises, and thence build an important structure upon an unsound foundation.

To a philosophical reader it will readily occur, that expansion is not the only principle to be considered in the conducting these experiments; for though the introduction of heat into a solid body, tends only to a separation of its parts, so as to cause the expansion of the whole, and that the re-union of those parts, and the consequent contraction of the whole, to its former state and bulk, is the immediate effect of the withdrawing of the heat so introduced; yet a fluid having undergone the same process, neither resumes its original volume nor density, on a return to its original temperature, but the former is diminished, and the latter increased; an effect ever produced by that diminution of quantity to which every fluid has a tendency, when exposed to a degree of heat superior to that of itself in a temperate state of the air; for the expansion of
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a fluid, or a partial separation of its component parts by heat, is ever attended by a total escape of such of them as are sufficiently volatile to be carried off by their mutual repulsion of each other, thereby causing that diminution of quantity and additional density just alluded to; a farther illustration of which will be the business of the subsequent section.

SECTION III. Of EVAPORATION.

THE general definition of evaporation, is that effect of heat whereby the lighter particles of a fluid, to which heat is applied, are separated from the rest, and fly off into the air, in the form of vapour, by which means the remainder becomes of a more dense consistency; or, if the separation be carried to the last extremity, some fluids will assume a solid form, and others will fly off entirely. The theory of this principle may be thus explained:

plained: in proportion as the heat insinuates itself into the body of the fluid, the particles of which it consists have a tendency to separate from each other; and when the heat becomes sufficiently strong, this separation actually takes place; at which period, the particles thus separated, becoming mutually repellent, rise from the surface of the fluid in a body, at equal distances from each other; and being hence specifically lighter than the same bulk of airy particles, rise up into the atmosphere like a cloud, till they reach that part which is of the same degree of rarity with themselves, unless arrested and condensed in their passage, by some intervening solid, which causes their re-union and return to that state, collectively, in which separately their avolation began. Those which do actually rise into the air, as just mentioned, remain suspended or stationary no longer than their acquired heat, and consequent rarefaction continues; but as that be-

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comes less, their repellent force decreases; the immediate consequence of which is, their descent in that progression which their re-union and condensation, or returning density, render unavoidable; still sinking as they become more dense, till of necessity they return to the earth.

On all fluids produced by chemical processes, the action and effect of evaporation are the same; i. e. the avolation or escape of the lighter particles, whereby that part of the fluid which remains is inspissated, or rendered of a more dense consistence than the whole was before the commencement of this action; but though the positive effect is the same, its relative consequence differs according to the nature of the fluid, which is its subject; and as all chemical fluids may be classed under the two general heads of *extracts* and *essences*, this difference of relative effect may be explained, by observing that evaporation tends to meliorate or enrich the former, and to injure or

or impoverish the latter. By the term *extracts* we would be understood to mean all artificial fluids impregnated with the dissoluble parts of solid bodies, either by decoction or simple infusion; and all natural fluids, such as vegetable juices, obtainable by spontaneous extraction or expression. By *essences* we would convey an idea of fluids, which have been the subject of fermentation, whereby their heterogeneous particles are assimilated, and in some measure rendered homogeneous; or of distillation, whereby the greatest degree of purity is effected which art can produce.

On the first mentioned species of fluid, evaporation having only the power of separating the aqueous parts, its certain effect is, a nearer approach, or more intimate union of the extracted parts of the dissolved body, on which its value depends, whence it gains in gravity what it loses in bulk; for the sum of its valuable particles remains the same, though

the volume of the fluid is diminished. On the other hand, all vinous fluids, the result of fermentation, and all distilled liquors, receive irreparable injury from evaporation; because the value of every fermented and distilled fluid, consisting in its most volatile parts, an exposure to this action, in causing their separation, deprives the fluid of the principle which constitutes its worth, and leaves it at length a mere *caput mortuum*. Common observation will confirm these different effects; for daily experience shews us, that by long exposure to the air only, a saccharine mixture will become a syrup, sea-water evaporate to salt, wine and beer lose their spirituousity and become vinegar, and distilled liquors retain only the simple element which formed their basis.

So far as the doctrine of evaporation is evinced by the visible effect of *steam*, rising from every heated fluid, it will be comprehended by all ranks and capacities; but to trace its efficient causes *ab origine*,

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to measure its relative influences, and to deduce its final consequences, requires a degree of philosophical reflection which few people, engaged in commercial pursuits, find either the leisure or inclination to bestow. In the brewery, though this active principle is ever before the artist's eyes, he is generally as little acquainted with its effects as if none existed; whence arise many disagreeable and disadvantageous errors, which it is hoped, an attention to these pages will effectually remove.

In order to apply the saccharometer for this end, we are previously to consider the different states and local situations in which the fluid to be assayed is necessarily found; the relative predicament in which the portion intended for the immediate subject of experiment stands; and the inference to be drawn from a comparative view of the whole.

The first of these considerations includes *extraction*, or the withdrawing the

liquor from the impregnating materials, and the consequent situation of the extract in the under-back. Secondly, *decoc-tion*, or the operation of boiling that extract in the copper. And lastly, *refrige-ration*, or the act of exposing a very large surface of the boiled wort in the cooler, preparatory to its being fermented.

With respect to extraction, or more properly the situation of the wort immediately subsequent to that part of the process, it were superfluous to note the effect of evaporation during its continuance in that state; because, what we want to ascertain there, is the acquired density of the whole, and not the specific gravity of a part, no farther than as that specific gravity is instrumental in ascertaining the aggregate density.

During the action of boiling, the effect of evaporation is not less critical than important; because, the due division of the aggregate density into the intended equal portions, or the certain regulation of the length,

length, depends very much thereon. For the quantity evaporated in the cooler may, in a great measure, be ascertained, since it generally bears a certain proportion to the whole wort turned out of the copper, including some consideration for the extent of the surface exposed; but in the great uncertainty which attends the vapour arising out of a fluid in a state of violent ebullition, we have no other means of determining the quantum evaporated, at any period of the operation, than by learning the then specific gravity of the given equal portion, which divided in the aggregate density, will give the number of those portions remaining at that period, and, of course, ascertain the amount of the evaporation; for instance, if there were sixteen of these portions in the extract, and we call the specific gravity three, the aggregate density will be forty-eight; and if at any period of the action of boiling we find by experiment, that the specific gravity be four, by dividing that in forty-eight

we know that the number of portions remaining is twelve, and consequently that four are evaporated. Were there no intervening obstacle to the immediate application of this doctrine, the rule would be general, and the event certain; but as such occurrences do necessarily and at all times exist, in practice, their consideration is indispensable, before any accurate conclusions can be drawn, or any correct estimate made, as will appear hereafter.

The two preceding circumstances being only of relative use, as conducive to the perfect regulation of the final unfermented state of the wort, the consideration of them is only presented as an object to be kept in view, in order with greater certainty to direct us to that final average gravity, which is the ultimate eventual consequence of all the evaporations to which the wort has been exposed, and particularly the immediate effect of that which results from refrigeration, or the act of cooling. As the quantum or amount of

of this last evaporation may be with sufficient accuracy ascertained; as the event is positive, and admits of no real or admissible correction; and as the effect of decoction or boiling, has an immediate governing influence on it; we may thence collect, that it is of the last importance to the intended regulation of the *length*, or final average gravity required, to bring the wort into the cooler in such a state as will produce that gravity, after the last evaporation has taken place.

To exemplify this, by enlarging on the case above quoted, we will suppose that from the sixteen given portions of the extract, whose specific gravity is three, and whose aggregate density is forty-eight, it were required to produce a standard wort, whose specific gravity, in a fermentable state, shall be six, it immediately occurs (without including the intervening obstacles before alluded to) that the whole evaporation must amount to one half of the wort; because six divided in forty-eight

eight produces eight, which is the number of portions remaining after the aqueous particles shall have been so far evaporated as to leave the specific gravity of the wort at six. Now if we estimate the positive and unavoidable evaporation which takes place during the passage of the wort from the copper to the cooler, including its continuance therein, at a one-ninth part of the whole, we can directly calculate the quantum of wort which ought to be in the copper, at the time of its being turned out, by saying, as eight (the intended volume of cold wort) is to nine, (the quantum of hot) so is any other intended quantity of cold wort, to its proportionate quantity of hot. This, in the present case, is nine parts of the original sixteen, because the quantum intended to be finally remaining is eight. Then, in order to calculate the specific gravity of the wort, when evaporated to those nine parts or portions, we are to divide forty-eight, the aggregate density, by nine, the required quantum

quantum of hot wort, and the quotient is 5.33, which denotes the specific gravity the wort ought to have when ready to be turned out of the copper, in order to produce the required specific gravity, or strength of the wort in the cooler, in a fermentable state.

This elucidation naturally includes an attention to a particular before mentioned; i. e. the relative predicament in which the specimen stands, which is taken out for the purpose of experiment, and which may be a false representation of the wort it was taken from, owing to the different effects of evaporation in different situations of the evaporating fluid, as will be more particularly shewn in its place. In all cases, the wort is to be guaged, and the specimen taken, at the same time, except in boiling wort, where the experiment is made merely for the purpose of ascertaining the quantity at that instant, as above explained; and in every state of the wort, the business is to be done at
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the very last period of its continuance in that particular state which is the subject of investigation. In the under-back, it has no other use than to prevent any addition (by farther draining from the mash-tun) from being made to the quantity of the wort after the guage and specimen are taken; for the business required here being only to ascertain the sum of the acquired density, and evaporation having no effect upon that, it is of no immediate consequence, whether the same be continued in a rarefied, or be reduced into a condensed state, or contracted volume; so long as the assay-jar, by being closed at the top, to prevent evaporation, preserves a perfect specimen of what the wort in the under-back would have been, at a similar degree of heat, had no evaporation taken place.

The experiment on the wort in the copper requires some little dexterity, to conduct it with efficacy and dispatch. The quantity of wort taken out, as a specimen, by the refrigerator, and

and plunged into cold water, to reduce it to an assayable heat; should, with all possible expedition, be submitted to the examination of the instrument; for a repetition of this being necessary, at different periods of the boiling, were the experiment to take up much time, the copious evaporation which takes place during that action might risque an increase of the specific gravity beyond the intended degree, and so defeat the very purpose of the enquiry.

A similar attention is necessary to the time of taking the specimen for experiment on the wort in the coolers (the particulars of which will be given in the practical directions) lest by the evaporation of the assay-jar, if the specimen be taken hot, being inferior to that of the cooler, the wort in the former should be a false representation of that in the latter; inasmuch as it would, in that case, be specifically lighter, and occasion an error disadvantageous to the brewer, who, on this occasion, has nothing to aim at but the production

production of his standard specific gravity, as a foundation for the standard strength of his liquor; which if he exceed, it is to his positive loss, and of which if he fall short, it is to his immediate discredit, and to his eventual disadvantage.

Having now, we presume, sufficiently explained the three grand principles whose agency is most powerful in the business which is the subject of our enquiries, we proceed to investigate the qualities of the materials which are to form the basis of our experiments.

SECTION IV.

Of the FERMENTABLE MATTER extract- ible from MALT.

THE value of malt consisting in its dissoluble parts, and these being obtainable in different proportions, according to the quality of the barley employed, or the skill of the maltster in conducting the process of its vegetation, it is matter of surprise

surprise that some certain means have not before been invented to regulate what the brewers term the *length* (i. e. the quantity of beer to be made from a given quantity of malt), rather by the *quality* than by the *quantity* of the malt made use of. When the brewer says he draws one and a half, two, two and a half, or three barrels from a quarter of malt, it means no more than that he employs so much malt to make so much beer, without conveying any determinate idea of the quality of either. He may, indeed, premise that his malt is of a good, bad, or indifferent quality, for the sake of distinction, and yet we are left to make a very vague guess at the result of its application; for the terms *good* and *bad* are totally indefinite, unless applied in reference to a standard established on the broad basis of mathematical certainty. In the present case, an instrument which will ascertain the quantity of the dissoluble parts, or of the fermentable matter extracted from malt
of

of every kind, will not only discriminate its value, but point out the value of the liquor produced from it, in explicit and communicable terms. This is what the brewer has long wanted; for though he could tell that stronger beer might be made from better malt, or from a greater quantity of the same malt, yet he has ever been at a loss to determine in what proportion it would be better, were such superiority or addition to take place. The instruments hitherto published, with the view of assisting him herein, have been totally incompetent to the purpose. Many reasons might be adduced in support of this assertion, without derogating from the ingenuity of the inventors or publishers; but one will suffice:—they were the attempts of men, who, not possessing the means of information adequate to the end proposed, could have no applicable foundation whereon to build a system of that certain and complete utility which the subject requires, and of which it is capable.

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The instrument now offered to the public, by shewing how many pounds avoirdupois of fermentable matter are contained in every barrel * of wort extracted from the malt, leads immediately to the discovery of what portion of the latter has been imbibed by, or incorporated with the extracted menstruum, and of course, what has been the product or intrinsic value of every quarter of malt employed; pointing out, at the same time, how much of that product is contained in a barrel of wort in a fermentable state, whether entire or a mixture of several; thence establishing a mathematical definition, which conveys positive ideas on the subject, and cannot be misunderstood.

By the long continued use of this instrument, in our own practice, as well as from its occasional application elsewhere, we are authorised to pro-

* Thirty-six gallons, beer measure, as before explained.

nounce it the most useful, because the most advantageous instrument the brewer can adopt. The discoveries it has laid open to our view, have been of so interesting a nature, that we have often been struck with astonishment to find that common observation and attention should be so inadequate to the purpose of securing or obtaining of very important advantages derivable from a very common profession, which has been so long involved in darkness and error, as to create a vulgar opinion that it neither requires nor admits of science nor system.

In the course of our experiments we have found, that by means of the instrument, we are enabled to estimate the intrinsic worth of every kind of malt, to the very great precision of the one-thousandth part of the fermentable matter extracted from every quarter employed. And by estimates made in this manner, we have discovered a great variety in malts, which, but for these discoveries, would

would scarcely have been deemed of different value. From such as have fallen under our observation in practice, during the three last years, we have selected the following, the respective value of which will be known by the sum of the fermentable matter severally extracted from them.

MALT from the barley of 1781.

N ^o	Colour.	Character.	Growth of barley.	Average prod. of ferm. matter
1	pale	well made	North Lincolnsh.	82 pounds
2	ditto	indifferent	ditto — —	75 ditto
3	ditto	well made	Norfolk — —	72 ditto
4	ditto	ditto —	Yorksh. woulds	82 ditto
5	brown	ditto —	ditto — —	78 ditto
6	ditto	ditto —	Ware, in Herts	56 ditto

MALT from the barley of 1782.

N ^o	Colour.	Character.	Growth of barley.	Average prod.
1	pale	well made	Yorksh. woulds	62 pounds
2	ditto	ditto —	Bremen — —	58 ditto
3	ditto	ditto —	Norfolk — —	67 ditto
4	ditto	indifferent	ditto — —	50 ditto
5	brown	well made	Ware, in Herts	52 ditto

MALT from the barley of 1783.

N ^o	Colour.	Character.	Growth of barley.	Average prod.
1	pale	well made	North Lincolnsh.	74 pounds
2	ditto	ditto —	Berwick on Tweed	63 ditto
3	ditto	indifferent	Yorksh. woulds	65 ditto
4	ditto	well made	ditto — —	75 ditto
5	brown	ditto —	ditto — —	72 ditto

The average products above-quoted are all deduced from the different produce of different brewings, made from the same parcel of malt, which sometimes varied a few pounds from the respective averages here stated; and this variation might arise from an essential difference in the malt itself, owing to the different degrees of perfection to which the vegetative process of different floors might have arrived, though consisting of the same kind of barley; or it might result from the difference in grinding the same malt rounder at one time than at another; for the intention of malting being the production of that saccharum, and other dissoluble parts * which

See *Theoretic Hints on Brewing*, page 39.

constitute

constitute the value of malt, it follows, of course, that in proportion as that process approaches to perfection, the increase of those valuable parts will be effected; and as the crushing of every kernel in pieces is indispensable to the setting at liberty its fermentable matter, it is obvious that if the operation of grinding be so carelessly performed, that a certain number pass through the stones unbroken, the product must be less in the proportion which these bear to the whole volume. Hence a continued attention is necessary to these preliminary particulars, as a foundation for those advantages which are to result from posterior considerations.

The different products of the different specimens above-stated convey important information to the brewer, and suggest a vast field of beneficial enquiry. By those we see that good pale malt, from stout barley, will produce, in the ordinary mode of practice, 82 pounds of fermentable matter; and of this produce the barley of

most of the inland counties is capable, and that of some will exceed it. We also see, in the fourth and fifth articles of the year 1781, that brown (not *blown*) malt produces 78 pounds per quarter, made from the same barley, and by the same process of vegetation, which in pale produces 82; and the Hertfordshire barley, in the sixth article, generally superior to that alluded to, made into brown malt, by the Ware practice, produces only 56. By the former practice, there is a deficiency in the produce of brown malt, of about 5 per cent, by the latter the loss is more than 30; a difference so very great, that were it not mathematically demonstrable, credibility would be staggered at an assertion which seems so severely to reflect on the judgment of many people, whose predilection for Ware malts has been of long standing, particularly in London, where they are most sought after, and bear the best price. It is, indeed, with the utmost respect that we submit to the consideration

of the gentlemen who stand in this predicament, the difference here announced between brown malts dried in the common method, and those which are *blown* by the precipitate mode practised at Ware and its environs.

Independent of the demonstration of this error by the saccharometer, we need only appeal to the understanding of any person, whether he be conversant or not in the nature of malt, to bear testimony of its existence, however indefinite in degree it may be found, in the want of the demonstrative means here alluded to. For were such a common observer to be informed, that every kernel of blown malt is of a magnitude exceeding the bulk of the barley from which it was made, in a ratio of four to three, or thereabouts, and that this excess of magnitude is occasioned only by a rarefaction of the air within, arising from a sudden application of violent heat to the green malt, which puffs up the outer skin like a bladder filled

with air, in which state it is fixed by the continuance of the heat, he will immediately conclude, that the cavity found in every kernel, though it may very well serve to buoy up its fellow, and fill the bushel, will produce no fermentable matter in the mash-tun :—*ex nihilo nil fit*.

It may be farther observed, on the defects of brown malts in general, compared with pale made from the same species of barley, that the process of brewing porter, and other beers, in which a portion of brown malt is necessarily introduced, is more productive of fermentable matter than that which common usage has adopted where pale malts only are employed ; the rational inference of this is, that the real deficiency of the former is greater than it appears to be in the experiments adduced ; because the products therein stated are those of the different processes just alluded to, and not comparative views of the products resulting from the same process ; a circumstance which,

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in the practical and separate use of brown and pale malts, very rarely occurs.

From the above view of the malts produced from the barley of 1781, which was in a state of general perfection, much more useful information may be collected. The two first articles are specimens of the produce of the same kind of barley, under the management of two different maltsters. In the former there is a superiority over the latter of 9 per cent; a considerable difference, to an amount which, in most commercial concerns, is deemed a fair profit; and yet these two parcels of malt would have passed, among common consumers, with this simple observation that *this sample is freer than that*; the difference in sale, would not, perhaps, have exceeded a shilling per quarter; and the brewer would have thrown them indiscriminately into the mash-tun, drawing his usual length from each, to the positive loss of 9 per cent, either in the quality of his liquor from the latter parcel, or in the obtain-

obtainable profits of his trade from the former; which ever might happen totally with the general quality of the malt he used.

The third article leads us to the detection of an error generally prevalent in the northern parts of the kingdom, which is the preference given there to Norfolk barley. Yet this preference has a very rational foundation, so far as it is found to be more vegetative, or to malt more freely than the native barley of those parts. Nevertheless, this is too often to be attributed more to the ignorance of the maltster, than to the quality just mentioned. If our specimen (made from a fair parcel of Norfolk barley, under a friend whose knowledge of the malting business is very extensive) be compared with that made from the Lincolnshire barley in the first article, we shall find a difference in favour of the latter of $12\frac{1}{2}$ per cent, and surely no person, after such a demonstration, would be weak enough to give a superior price

price for a commodity deficient in value to so considerable an amount.

The barley of the year 1782, presents us with a melancholy spectacle of the effects of that ungenial season. The first article exhibits the produce of the same maltster, occupied upon barley from the same place which is quoted in the fourth article of the preceding year, and "what a falling off is there!"—an advance of 100 per cent in price, with a reduction in quality of near 24 per cent more, must necessarily have reduced the brewery to a situation to which few other professions are liable; because most manufactories advance the price of the commodity in proportion to the advance on the materials, a circumstance which can rarely take place in the brewing business. The barley from Bremen, mentioned in the second article, though apparently much inferior to the preceding, was nearly equal in produce; because it germinated freely, whilst a great part of the other remained unmalted.

malted. And this accounts for the Norfolk barley of that year having a real superiority. It was gathered in so much better order than the barley of the northern counties, which was in a great measure spoiled, that opposing the best of both sorts to each other, it was both superior in appearance and produce. From a similar cause, there appears less difference between the two seasons of the blown malt of Hertfordshire than in the rest, for the southern situation of that county is generally more favourable to the husbandman, in gathering the fruits of his labour, than can be expected in the more northern counties.

The last season (1783) though yielding a providential relief, was still very inadequate to the supply of the distressing deficiency caused by the preceding year. The backwardness of the northern harvests subjecting them to the autumnal rains which took place after the southern counties had finished their harvests, did
irreparable

irreparable damage to the barley; whence the obvious difference between the produce of that and the barley of 1781, though happily much superior to that of 1782. The falling off observable in the third article, arose partly from the indifferent quality of the barley, which was sprouted and much injured by the weather, and partly from the want of attention or skill in the maltster; from which causes it barely exceeded the second article, which was from very thin barley produced in the neighbourhood of Berwick upon Tweed, but which worked tolerably well upon the floor. It is also worth observation, that the deficiency in the brown malt of the fifth article, bears nearly the same proportion to the quality of the pale, in the fourth, that it did on the same occasion in 1781.

We wish it to be here particularly noted, that the several sums of the fermentable matter extractible from different malts, as above stated, are those obtainable in the

the ordinary way of practice; but that by a particular modification of the extracts, and regulation of the process of brewing, an addition thereto may be made, well worthy the brewer's attention. It is impossible to say what may be the amount of this addition in every case, because it must necessarily vary with that variety of practice observable in various situations and circumstances; but this we may venture to assert, that the general adoption of that mode of practice, which is meant to be reserved for particular communication, would effect a saving in the consumption of malt, in this kingdom, of at least 5 per cent, without the smallest diminution of the respective strength of the liquor produced from it. And we are confident in the assurance, that the advantage here alluded to, is not the hypothetical conclusion of a visionary system, but the real, solid, attainable benefit, arising from a particular mode of practice, which we have successfully adopted for a length of time sufficient

sufficient to warrant its reality; nor is it over-rated, in the general estimate, if we may be allowed to judge from a comparison of our own practice, with that of others known to us, in different parts of the kingdom. We also make a reservation of the event of this comparison, for no other reason than the probability that its publication might not be deemed proper to meet the eye of every reader.

From the foregoing premises may be drawn inferences very favourable to the general use of the saccharometer, in the brewing business; and should its reception be such as the importance of the subject seems to claim, we may hereafter be induced to recommend an apparatus for ascertaining the value of malt to the purchaser or maker, independent of the consumer; in order that the buyer and seller of that article may adopt a clear and explicit language, conveying definite ideas, which by common usage may become as familiar to each other, and as well understood

flood, as the terms made use of by the importers and dealers in spirits; the value of which, but for the use of a similar instrument, would be as vague and indefinite as that of malt now is, estimated by the barbarous test of mastication, or the equally uncertain one of floating in water, productive of no clearer language than is couched in the very equivocal terms of *bad, flinty, steely, hard, stiff*, and their opposites, *good, tender, free, &c. &c.* to which no positive idea can be affixed, because they are relative to no standard of comparison.

SECTION V.

Of estimating the VALUE OF MALT, and of regulating the LENGTH, or establishing a standard strength for beers of every denomination, by the fermentable matter extracted.

FROM what has been said in the foregoing section, it will readily be suggested, that as the value of malt arises entirely
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from the quantity of fermentable matter it produces, the language of brewers, adopting the use of the saccharometer, will be, that "this or that malt producing so many pounds more or less per quarter, is of course in that proportion more or less valuable;" and if we establish 82 pounds produce as the standard of what is now termed *good malt*, and estimate it somewhat lower than the present exorbitant price, viz. at 41 shillings per quarter, for the sake of an easy calculation, we shall see that six pence per pound is the value of the fermentable matter of malt, estimated at that price per quarter; and that, therefore, the proportionate value of the malts of 1781, quoted in the preceding section, will stand precisely thus:

	per Quarter
1. Good <i>pale malt</i> , from Lincolnshire barley	£ 2 1 0
2. Indifferent ditto - - ditto - -	1 17 6
3. Good <i>pale malt</i> , from Norfolk barley	1 16 0
4. Ditto ditto from Bridlington barley	2 1 0
5. Good <i>brown malt</i> , from the same kind of barley	1 19 0
6. Ditto ditto, from Ware (<i>blown</i>)	1 8 0

On this view of the real, intrinsic value of the above malts, which value is demonstrable to as great certainty, and by as easy a mode, as the strength of spirits is ascertained, no farther comment is necessary than the simple observation, that the difference in the first and second articles arose from the different skill of the different maltsters by whom they were made; the inferiority of the third resulted from that inferiority of the barley, the defects of which the best artist cannot supply; the fourth and fifth shew the disadvantageous effect of drying malt brown, though of equal quality on the floor, and cured upon the same kiln; and the sixth expresses the deficiency produced by the practice of *blowing* up three kernels till they nearly occupy the space of four, the natural inference of which is written in such broad characters as to preclude the necessity of farther display; for "he who runs may read."

To reduce into order this very great irregularity, and to establish a standard

by which the essential value of all malts might be estimated, and that every relative of that estimate might be reciprocally communicated amongst those interested in the sale or consumption of malt, in clear, unequivocal terms, it would be necessary to lay down certain rules, and to establish a certain criterion of perfection, by which the quality of every species might be immediately tried, and explicitly communicated, as soon as discovered; in which business the term *par* being adopted by the dealers in malt, with the same intention as that of *proof* has been by the dealers in spirits; and that *par* being fixed at 70 or 80 pounds per quarter produce, the distinction of so many pounds above or below *par* would be as definite and comprehensive to the former, as that of so much above or below *proof* is to the latter; particularly if recourse could be had to an apparatus similar to that intimated in the last section, to correct their judgment and corroborate their assertions.

As the mode of forming this estimate of the fermentable matter extractible from malt consists, at present, in knowing the number of barrels of wort extracted from it, and discovering how many pounds each barrel contains, we are thence led to calculate the aggregate or sum of the fermentable matter produced by the malt employed, and to divide that aggregate into so many portions, or equal parts, as we wish to have barrels of wort in a fermentable state, or barrels of beer after the fermentation is finished; thereby providing for the establishment of a certain standard, or uniform strength, let the quality of the malt employed be good or bad. Hence, if the brewer has generally been accustomed to the use of indifferent malt, and should become possessed of some of superior quality, he may, at a certainty, reap every advantage accruing from that superiority, and not blindly waste it in a superfluous strength of his liquor; or, if he has commonly used good malt, and should accidentally purchase or
make

make a parcel of inferior quality, he needs not risque the loss of his credit by an unforeseen or unintended diminution of that strength which the consumer of his liquor expects to find; neither of which can be avoided by the present random estimate of *so many barrels per quarter*, in lieu of the more accurate one, here inculcated, of *so many pounds of fermentable matter per barrel*.

To accommodate this to the practice of every brewer, no general standard is necessary; because the criterion of perfection in malt-liquors, as in most other articles of domestic consumption, existing principally in the taste of the consumer, and that taste being as various and indefinite as the complexions, inclinations, and manners of the deciding parties, it is incumbent on every brewer to fix upon that standard strength, or final specific gravity of his wort, which by experience he finds productive of the required strength of his liquor. For instance, should he discover, from a repetition of experi-

ments, founded on his usual mode of practice, that 25 pounds per barrel is the gravity which produces sufficient strength for his general trade; he is then to establish that, in his own mind, as his standard strength, which he ought always to produce, and which he needs never to exceed; for, should the aggregate extract of his malt produce, on a division into the number of barrels usually contained in his length, a superior gravity, only in the ratio of 1 pound per barrel, making 26 instead of 25 pounds, he would lose an attainable advantage of six pence per barrel (at the price of malt above quoted) if he did not make such an addition to his length, as should liquidate that superiority, and leave his wort in its standard state. On the contrary, should the aggregate extract, on a similar division, fall short of the intended standard, the length, in the present process, should be lessened by extraordinary evaporation, and, in the future, by less copious extracts.

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From a transient view of this subject, a person might be led to imagine, that if 80 pounds, for instance, are extracted from a quarter of malt, a length of two barrels per quarter would of course produce 40 pounds per barrel; that of two and a half, 32 pounds; and other lengths in the same proportion. This, however, would be a fallacious estimate. The quantity of hops used makes a considerable and perpetual variation herein; for though the dissoluble parts of that vegetable produce some addition to the gravity of the wort, yet the quantity imbibed by the hops exceeds the amount of that addition in so great a degree, as to make a considerable and irretrievable diminution in the aggregate of the fermentable matter extracted. But, in order to convey some idea of this matter, it may be observed, that the general product, by the general practice of the brewery, of what is termed *good malt*, is, upon an average, nearly as follows

	Per Barrel,
Burton ale, of 36 to 40 gallons per quarter	40 lb.
Country ale, of 2 barrels	— 32 —
Ditto, of 2 barrels and a firkin	— 28 —
Ditto, of 2 barrels and a half	— 26 —
Porter, of 2 barrels and a half	— 25 —
Ditto, of 2 barrels and three firkins	— 24 —

These averages are, nevertheless, so liable to variation, from the variety of processes adopted by brewers, and the various qualities of the malt made use of, that they are by no means intended as certain standards, capable of becoming a rule for general practice; though an occasional reference to them may not be unuseful.

But, to return to the regulation of the length, or final average gravity of the wort, we have to observe, that as the amount of the diminution above mentioned will be the subject of our future discussion, we shall here only intimate another difficulty which occurs in attempting to make the most advantageous division of the aggregate extract into the intended

intended proportions, and this exists in the incompetency of the ordinary practice of the brewery to the obtaining *all* the fermentable matter which it is practicable to extract from malt, the explanation of which is reserved for the particular communication before alluded to.

To remove, however, those obstacles which occur in the regulation of so much of the fermentable matter as is obtainable in the common mode of brewing, an attention to the following considerations is necessary; viz. that every wort to be assayed must previously be brought to that degree of heat which is established as a standard temperature for the instrument; or a calculation must be made, to reduce it to that temperature, in order to determine what its quantity and quality would be, when so reduced; because the expansion, or increased volume of fluids of different densities, is not in the same ratio by the application of the same degree of heat, nor is the difference of their increase

crease in proportion to their different densities. To obviate this difficulty, we have been induced to give, with the instrument, the *Table of Expansion*, which, shewing the degree of expansion in worts of different gravities, from 1 to 60 pounds per barrel, enables us to ascertain the different volumes of the same quantity of wort at different degrees of heat, from 50 to 200, by Farenheit's thermometer; as well as the *Table of Heat*, before mentioned, pointing out the value or real specific gravity of worts of the same variety, noted at every pound per barrel, and at every degree from 50 to 100, by the same thermometer; which tables include every practicable density and heat. To have extended this table beyond its present limits, would have subjected the investigator to inconveniences which will be mentioned hereafter.

Being enabled hereby to determine, with precision, the actual specific gravity of every extract, when at 50 degrees

degrees of heat, and to ascertain what would be the precise quantity, at the same temperature, so as to calculate therefrom the number of pounds of fermentable matter contained therein; we are next led to consider how this aggregate of fermentable matter shall be so disposed, after the action of boiling, and its subsequent cooling shall have taken place, as to produce the exact number of pounds per barrel, which we have established as a standard, productive of the required strength in our liquor.

In extracting from the malt the requisite quantity of wort, the experienced brewer will not be at a loss, but in the evaporation which takes place in the copper, especially where long boiling is required, the uncertainty is so great that we can never be assured, by any rule hitherto known in the brewery, that we shall produce the desired quantity, and are thence frequently led into great and disadvantageous irregularities.

To

To surmount this difficulty, were no hops employed, we need only have recourse to the rule mentioned under the article *evaporation*, and estimating thereby how much of the aqueous parts of the wort ought to be evaporated, during its continuance in the copper, immediately calculate its required gravity at the moment of its being turned out. Thus, if a wort containing 40 barrels, at a gravity of 30 pounds per barrel, were required to be boiled down so as to produce 40 pounds per barrel, in a fermentable state, the portion to be evaporated must of course be one-fourth of the whole quantity, or 10 barrels; but supposing 3 of those 10 barrels to be the amount of the evaporation, from the period of turning the wort out of the copper to that of its being in a fermentable state, the evaporation of the copper will be only 7 barrels. Whence dividing 1200 pounds, the aggregate of the fermentable matter contained in the wort, by 33, the number of barrels to which it

is to be reduced in the copper, the quotient will be somewhat more than 36; which would indicate the specific gravity the wort ought to have, when evaporated by boiling to 33 barrels. As soon therefore as the instrument (by a repetition of occasional experiments) shews the wort to be 36 pounds per barrel, it should be immediately *struck*, or turned out of the copper, and the then quantity would undoubtedly be 33 barrels, though, from the great irregularity of a violent ebullition, the guaging rod could not have ascertained the quantity at that time.

But since hops must be made use of, we have to encounter fresh difficulties arising therefrom. In addition to the 1200 pounds of fermentable matter, in the case before us, there will be to include the extractible parts of the hops employed; from the sum of which is to be deducted the quantity of wort imbibed by the hops, or rather the amount of the fermentable matter contained in the quantity so imbibed,

bibed, and the difference will be the net aggregate of the fermentable matter extracted; which divided by the standard strength intended, the quotient will shew the number of barrels producible therefrom. The application of the instrument herein will be precisely the same as in the case just quoted, with the advantage of proving the total incompetency of the guaging rod; because the space occupied by the hops, the amount of their absorption, and the ebullition of the worts, render all attempts to ascertain the quantity by a guage nugatory and impracticable.

These considerations seem to claim the attention of every brewer who boils his worts by time, particularly during so long a term as is requisite in the porter brewery; in which the irregularity of length is sometimes very considerable. If the end of decoction (exclusive of the purpose of extracting the preservative qualities of the hops) be to evaporate a certain portion of the aqueous parts of the wort, in order to
inspissate

inspissate and render more preservable the remainder, it appears quite indifferent whether the obtaining that end, to the degree which the experience of the brewer has shewn to be necessary, be effected in one hour or in five hours. When once obtained, whether in a short or a long time, by means of a quick or a slow fire, by a violent or a gentle ebullition, the application of the saccharometer will assure the brewer that he needs neither err in this quantity or quality; "a commendation devoutly to be wished" by all who are interested in the emoluments of large breweries.

To facilitate these several particulars, the average amount of the extract from the hops is hereafter ascertained in its proper place, and a *table of the quantity of wort imbibed by different quantities of hops*, is added to those before mentioned, as given with the instrument; to which is likewise added a *table of measure*, reducing barrels of 36 gallons into those of 34, for the
the

the use of such persons in the country whose barrels are of the latter contents.

The utility of these tables will be obvious to those who are not expert at calculation; and to those who are, the saving of their time and trouble will be some recommendation of them.

From what has been premised on the subject of the theory and principles of the saccharometer, we presume the reader will be sufficiently prepared to enter upon the practical part, to which we now proceed.

STATICAL

STATICAL ESTIMATES

OF THE

MATERIALS OF BREWING;

OR, A

TREATISE

ON THE

APPLICATION AND UTILITY

OF THE

SACCHAROMETER.

PART II.

Containing **EXPERIMENTS and PRACTICE.**

IN order to apply, in practice, the doctrines inculcated in the former part, it may be necessary to advert to the experiments upon which they are founded, and to recur to those practical corroborations which at once exemplify, illustrate, and establish them.

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For this purpose we will set the general process of brewing before us, and note the application of the saccharometer in the several stages of its progress as they occur.

SECTION I.

Of applying the Instrument to the simple Extract, or the WORT IN THE UNDER-BACK.

SO soon as the *tap* is spent, or the wort all drained from the malt into the under-back, by dipping it with a guage we ascertain the number of barrels extracted; by taking the heat of it, we determine its state of expansion; and by preserving a specimen in the *assay jar*, we are enabled to discover its specific gravity, the moment it is cooled to an experimentable degree of heat *. In this business, as we have

* The reason of limiting the degree of heat for experiments to 100, is to prevent incorrectness in applying the instrument; for, at a higher degree, the heat being less stationary, an error might arise from the decrease which would take place during the experiment.

before

before intimated, the circumstance of evaporation is of no account; because the wort is immediately pumped up into the copper, and is subject to no material evaporation, but what is the object of subsequent attention. Its state of expansion, however, requires consideration; because the guage, taken as above, can only determine the volume, or number of barrels, at the degree of heat which it then happens to contain, but does not shew the number of barrels to which the same would be contracted, at any of those degrees to which the application of the instrument is necessarily limited; and therefore, without this consideration, the quantity of wort would be falsely estimated, and the aggregate acquired density, or sum of the fermentable matter extracted, would of course be wrong.

This circumstance induced us to investigate the principle of expansion, as relative to the business in hand, by means of the apparatus before described, and to form

the table, on that subject, before referred to; by the assistance of which we come at once to the desired information. For instance, in a brewing of 24 quarters of malt, our first wort in the under-back was 32 barrels, the heat of which being 145 degrees, by Farenheit's thermometer, we took out our specimen, and cooling it in the assay jar, found its specific gravity to be 28.25 pounds per barrel. On referring to our experiments on the subject of expansion, we found that in a wort of that strength, the amount of the expansion at 145 degrees, is in a ratio of 1.69 per cent; i. e. 100 barrels of wort of that specific gravity, and at that degree of heat, would be 1.69 less in bulk, or only 98.31 barrels in the whole, when cooled to 50 degrees, supposing all evaporation to have been prevented. Therefore, as 100 is to 98.31, so is 32 to 31.47; which shews that our 32 barrels, if suffered to have cooled to the standard temperature of the instrument, would have been only 31.47, or

or not quite 31 barrels and a half. To find the aggregate of the fermentable matter extracted in this wort, we multiplied 31.47, the quantity, by 28.25, the specific gravity, and the product was 889 pounds.

Our second wort, from the same malt, was 30 barrels, at 160 degrees of heat, and its specific gravity was 17.6 pounds per barrel. Making again the same reference as in the former wort, we found that the amount of the expansion of this wort was 2 per cent; and that, by the same rule of proportion, our 30 barrels were only 29.4 at the standard temperature. Hence the product of that quantity of wort, multiplied as before by its specific gravity, was 517.4 pounds, the aggregate of the fermentable matter contained therein.

A third wort was 31 barrels at 170 degrees of heat, and its specific gravity was 9.25 pounds per barrel; the expansion of which amounting to 2.33 per cent, we found, by similar modes of enquiry, that

there were only 30.26 barrels, the aggregate fermentable matter of which was 279.9 pounds.

These aggregates being all added together, the sum of the fermentable matter extracted appeared to be 1686.3 pounds.

Without having taken into consideration the state of the expansion of these worts, they would have stood thus :

<i>Wort.</i>	<i>Barrels.</i>	<i>per Barrel.</i>	<i>Pounds.</i>
First	32	at 28.25 produces	904.0
Second	30	— 17.6 —	528.0
Third	31	— 9.25 —	286.7
Apparent sum of the several aggregates of the fermentable matter —			1718.7
From which deducting the true sum			1686.3
The difference is			32.4 lb.

being the amount of the error which would have arisen from a calculation founded on these erroneous principles.

In conducting these experiments we had always the precaution to gauge the wort, and take the specimen out of the under-back,

back, as before recommended, just at the time the wort was about to be pumped into the copper, the mash-tun cocks being turned off. Had it been heedlessly guaged at an earlier period, the draining from the mash-tun, however inconsiderable in appearance, might have made too considerable an addition to the quantity to have passed unnoticed; and had the specimen been drawn from the last running of the wort, which is of a more dense consistence than the first, instead of being taken out of the under-back, an error of some importance, on the contrary side, might have been occasioned thereby.

The covering up the specimen in the assay jar had, also, been as carefully attended to, in order to be assured, that as it was at the moment of being taken out, an exact sample of the wort at that time in the under-back, though too hot to have its gravity immediately ascertained, so it might continue its faithful representative when reduced to a lower temperature; for

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though an evaporation takes place during the time of its cooling, yet the vapour being confined by the cover, and prevented from escaping, becomes condensed by the coldness of the metal, and returning in drops, again mixes with the wort, which is thereby restored to the same state in which it was when first put into the jar.

The result of these observations being duly noted, we had only to wait the event of the subsequent parts of the process, the investigation of which was as follows.

SECTION II.

Of the Effects produced in the Density of Worts by BOILING, and by the Addition of Hops.

HAVING boiled the first wort, above mentioned, its usual time, we found that of the 31.47 barrels there remained only 21.5 when properly cooled; and on applying the instrument to discover its specific gravity, we perceived that it had increased

increased to 34.25 pounds per barrel. Multiplying, therefore, 21.5 by 34.25, the product of which was only 736.375 pounds, and deducting that sum from 889 pounds, the sum of the fermentable matter originally extracted, we discovered a deficiency or apparent loss of 152.625 pounds of that fermentable matter. Being well aware that this deficiency could not arise from evaporation, which, as before explained, can only carry off the aqueous particles, we were convinced that the absorption of the hops used was the true cause of the loss, which induced us to commence an immediate enquiry on that subject.

In order to discover what addition is made to the density of wort by hops, as a preliminary step to the discovery of what they imbibe, we took half a pound of good Kent hops, and boiled them in water, as under:

First, in one hour, 12 pints of water were reduced to 7.5 pints, the specific gra-

vity

vity of which was 1.75, or one pound and three-fourths per barrel.

2. The same hops in 12 other pints of water, which in one hour was evaporated to 9.4 pints, whose specific gravity was 0.5, or half a pound per barrel.

3. The same in 12 pints more, which in the same time evaporated to 9.8 pints; the specific gravity 0.22.

4. The same in 12 pints more, which in the same time evaporated the same amount as the last, and its specific gravity was only 0.125.

From these experiments it is evident that the first extract is nearly two-thirds of the produce resulting from four fresh applications of water, and as the hops used herein were in the proportion of 19 pounds to a barrel, in the first experiment, the extract of which was so inconsiderable as 1.75 pound in 7.5 pints, we thought the succeeding extracts too immaterial to be noticed in practice; for which reason, as well as for considerations which will appear

appear hereafter, we included the application of the first extract only.

The proportion of hops above mentioned was thus ascertained: as 7.5 pints, the quantity of the first extract, are to 0.5 pound, the quantity of hops used, so are 288 pints, the contents of a barrel, to 19.2 pounds, the proportion of hops per barrel, in this experiment. And the true specific gravity of the first extract was thus found: we divided 19.2, the hops per barrel, by 36, the number of gallons per barrel, and the quotient 0.53 shewed the proportion of hops per gallon. Then saying as 0.5, the quantity of hops used in the experiment, is to 0.53, the proportion per gallon, so is 1.75, the specific gravity of the quantity extracted, to 1.86, the true specific gravity of the extract. Finding this so very near the proportion of 10 to 1, to avoid fractions, and unnecessary references to tables, we established it as a rule, that 10 pounds of hops will produce 1 pound additional density

density to the wort; and accordingly for 300 pounds used in the wort above quoted, we added 30 to the sum of the fermentable matter (889) making in the whole 919 pounds.

We are not unapprized of an objection which might be made to the general establishment of this calculation of the hop-extract, on account of the irregularity which different lengths of time in boiling might occasion, and of the greater facility with which water may extract the dissoluble parts of hops, thence tending to invalidate this proportion as inapplicable to an extract made with a dense wort; but as we have only taken the first extract into our account; as other experiments of the same nature have tended to establish this proportion; and as its accuracy has been sufficiently confirmed by actual practice, it may be relied on to answer the purpose of the nicest practitioner.

Our

Our next enquiry was directed to the discovery of the quantity of wort generally imbibed by hops, in order to enable us to account for the present deficiency, and to ascertain the amount of such as must necessarily happen in future.

We inclosed half a pound of good hops in a tin case, perforated with small holes, and sufficiently large for the purpose, suspending it by a string in the middle of a copper of first wort, which was suffered to boil one hour and a half. It was then hung up to drain till the inclosed hops were in the same state with those in the hop-back, from which the whole wort had drained. We next weighed a pint of the wort, when at the standard temperature, and found it to weigh 9862 grains net. The original weight of the hops (calculated at 440 grains per ounce, from the necessity of making use of weights so proportioned) was 3520 grains, which by the addition of the imbibed wort was increased to 25080. The dis-

soluble

soluble parts of these hops which must have been extracted, amount to 352 grains, according to the proportion above stated, which being deducted from 3520, their first weight, there remained 3168 grains, being the then net weight of the hops, independent of the worts actually imbibed. We had now to deduct the said 3168 grains, net weight, from 25080, the gross weight of the whole, and the difference, 21912, was the true weight of the wort imbibed by the hops; which being divided by 9862, the net weight of one pint, the quotient, 2.22 pints, shewed the exact amount of the quantity imbibed by half a pound of hops. According to this calculation, somewhat less than 65 pounds of hops will imbibe one barrel of wort, when well drained; but, as the expedition required in practice will not admit of a scrupulous observance of every nicety, we find, from long experience, that the average may be estimated at 60 pounds of hops, as generally imbibing

imbibing a barrel of wort; which estimate, also, from different experiments, wherein measure instead of weight has directed our calculations, is sufficiently corroborated and confirmed.

Having procured this information, we discovered that our 300 pounds of hops had imbibed 5 barrels of wort, which, at 34.25 per barrel, produced a deficiency of 171.25 pounds in the fermentable matter it contained; deducting, therefore, that sum from 919 pounds, the aggregate of the extract of both malt and hops, we found that 747.75 pounds were all that we could expect to remain in the wort, at a fermentable temperature, *i. e.* when it had undergone the whole process, fermentation only excepted.

On comparing this sum with the actual quantity of fermentable matter found in the wort (736.375 pounds) there appeared still a deficiency of rather more than 10 pounds; which may be accounted for by the

the probable supposition that there might have remained a small quantity of wort in the hops, at the time they were returned into the copper, which would have drained out, had they remained a little longer in the hop-back. Eleven gallons more would have effected the required balance; and this, we presume, is as near an approach to scrupulous accuracy as is consistent with the regular dispatch of real business.

Our second wort having boiled its allotted time with the hops from the first, we perceived that the 29.4 barrels at 17.6 were evaporated to 22 barrels, and its specific gravity was increased to 25.5 pounds per barrel. Multiplying these together, the product (561 pounds) shewed that there was an addition made to the fermentable matter of the simple extract, amounting to 43.6 pounds. To discover how this could happen, we considered that to the 517.4 pounds first extracted, the hops carried with them, from the

the first wort, 171.25 pounds, which we found they had imbibed, making in the whole 688.65 pounds; but as they still retained 5 barrels, the amount of the quantity first imbibed, we considered that the 5 barrels then imbibed, having displaced the former 5, were only to be estimated at the rate of the specific gravity of the displacing wort; which being only 25.5 pounds per barrel, by multiplying that sum by 5, we discovered the amount of the fermentable matter then remaining in the hops to be 127.5 pounds, which, deducted from the gross aggregate, 688.65, shewed that the sum of the fermentable matter at that time in the wort should have been 561.15 pounds; and as the actual quantity appeared 561, the accuracy of this calculation is confirmed to a degree of nicety hardly to be expected on so practical an occasion.

Submitting to a similar process our third wort, the original quantity of 30.26 barrels at 9.25, was reduced to 20.5, at

16.5 pounds per barrel. These multiplied together shewed the sum of the fermentable matter to be 338.25 pounds, which exceeded that of the simple extract (279.9 pounds) to the amount of 58.35 pounds. Pursuing the same mode of investigation, we added the 127.5 pounds, brought into this wort by the hops from the last, to 279.9, the fermentable matter extracted, and the sum of them both was 407.4 pounds. Then deducting therefrom 82.5 pounds, the amount of the fermentable matter contained in the 5 barrels of this wort retained, at 16.5, (the same quantity of the second having been displaced thereby, as before) we found that the sum of the fermentable matter of the whole wort should have been 324.9 pounds, but in the actual produce (338.25) we found an excess of more than 13 pounds, amply supplying the deficiency of the first wort; a circumstance probably occasioned (as was before suggested) by a want of that time

to drain from the hops, which the last wort can always be allowed.

To render this business the more familiar, we will recapitulate, and bring the whole into one point of view.

1. Fermentable Matter extracted from 24 Quarters of Malt.

	lbs.
First wort 31.47 barrels at 28.5 lbs. per bar.	889.0
Second, — 29.4 ——— 17.6 ———	517.4
Third, — 30.26 ——— 9.25 ———	279.9
Total, 91.13 bar. at 18.52 lbs. per bar.	1686.3

2. Fermentable Matter remaining after boiling the Worts, including the Extract of Hops.

	lbs.
First wort 21.5 barrels at 34.25 lbs. per bar.	736.37
Second, 22.0 ——— 25.5 ———	561.00
Third, 20.5 ——— 16.5 ———	338.25
Total, 64.0 bar. at 25.55 lbs. per bar.	1635.62

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3. Cal-

3. Calculation of the fermentable matter which ought to have remained, according to the preceding doctrine.

First wort, produce — 889.0 lbs.

Add, extract from 300 lb. of hops 30.0

919.0

Deduct, for 5 barrels at 34.25, }
imbibed by the hops -- } 171.25

Net remainder — 747.75 lbs.

Second wort, produce 517.4 lbs.

Add, fermentable matter brought
in with the hops from the }
first wort — — } 171.25

688.65

Deduct, for 5 barrels at 25.5, }
having displaced those first } 127.5
imbibed — — }

Net remainder — 561.15 —

Third wort, produce — 279.9 lbs.

Add, fermentable matter brought
in with the hops from the }
second wort — — } 127.5

407.4

Deduct, for 5 barrels at 16.5, }
having displaced those im- } 82.5
bibed of the second — — }

Net remainder — 324.9 —

Total — 1633.8 lbs.

4. Correspondence between the first and final states of the aggregate fermentable matter extracted.

First State.

Sum of the extract from 24 quarters of malt contained in 91.13 barrels of	}	1686.3 lbs.
raw wort — — —		
Extract from 300 pounds of hops	—	30.0
Total	—	1716.3

Final State.

Sum of the fermentable matter contained in 64 barrels of wort in a	}	1635.62 lbs.
fermentable state — —		
Imbibed by, and remaining in the	}	82.5
hops, per calculation — —		
Total	—	1718.12

By the foregoing state of the dissoluble parts of the malt and hops employed in brewing, we perceive, that however the bulk of their containing vehicle be changed, or their local or relative situation varied, the sum or quantum first extracted remains exactly the same, so far as we can discover by the means made use of for

I 3 ascertaining

ascertaining it. And that those means are accurate may be readily inferred from the consideration that the difference between the actual and the calculated produce of the 24 quarters of malt above quoted, does not amount to 2 pounds in the sum of 1635; a degree of accuracy to which general practice can hardly expect to attain.

In the course of our own practice, we must acknowledge, the correspondence, as above stated, has not always been so very accurate, the cause of which will be intimated in the succeeding section; but we are bold to affirm, that the result of our processes, through a long and continued adoption of this system, has so generally tallied with the principles therein inculcated, as to establish and confirm the truth of them, beyond a shadow of doubt.

Having thus taken a general comparative view of the fermentable matter, in its origin and in the period of its entrance into a state of partial annihilation, in the gyle tun, we proceed now to the particulars of its progress.

SECTION III.

Of the application of the instrument during the boiling of the wort, in order to REGULATE THE LENGTH, or produce the specific gravity intended.

THE irregularity and inequality of the produce of the same quantity of wort having been matter of frequent observation, we determined to enter into an investigation of that business, with the view of establishing the means of its prevention, on the sure basis of practice and experience.

At the time, therefore, that the first wort was going to be turned out of the copper, we took a quantity, filled an assay-jar, and covering it close, to prevent evaporation, suffered it to cool. We then tried its specific gravity, and found it to be 31.76 pounds per barrel. Dividing this sum in 736.37, the amount of the fermentable matter remaining in the wort,

after the absorption of the hops had taken place, the quotient 23.18, expressed the number of barrels of wort in the copper, at the period above mentioned. The quantity of the cold wort, 21.5 barrels, being deducted from this, the remainder, 1.68, shewed the amount of the evaporation, or the quantity of wort evaporated, in passing from the copper to the cooler, including its continuance therein.

Proceeding in the same manner with the second wort, we found its specific gravity, at the period above indicated, to be 23.46 pounds per barrel ; which being divided in 561, the final aggregate fermentable matter contained in the wort, the quotient was 23.91 barrels, being the quantity of wort then in the copper. Deducting from this the quantity of the cold wort, 22 barrels, the amount of the evaporation appeared, by the difference, to be 1.91 barrel.

The third wort having undergone a similar process, its specific gravity proved to be 14.92 pounds per barrel ; which
being

being in like manner divided in 338.25, its aggregate fermentable matter, the quotient, or quantity of wort in the copper, at the above quoted period, was 22.66 barrels; from which having deducted 20.5 barrels, the quantum of the cold wort, the difference shewed the amount of the evaporation to have been 2.16 barrels.

In order to make a general application of these discoveries, we compared the three evaporations together, and found their relative proportions to differ considerably, as will appear from the subsequent view of them.

The first wort of 21.5 barrels, at 34.25 pounds per barrel, had evaporated 1.68 barrel, which is in the ratio of 7.7 per cent.

The second, of 22 barrels, at 25.5 per barrel, had suffered the greater evaporation of 1.91 barrel, or to the amount of 8.65 per cent.

The third, of 20.5 barrels, at 16.5 per barrel, had evaporated so much as 2.16 barrels, or 10.5 per cent.

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This comparative view suggested to us the idea, that worts of different densities evaporate in different proportions, *ceteris paribus*, and determined us to proceed in such enquiries on the subject as, being the result of present experience, should become the rule and standard of future practice, without having recourse to the minutiae of philosophical disquisition, which the rude magnitude of our utensils rendered inadmissible or inefficient.

From a long and tedious course of experiments, which, we must candidly acknowledge, did not always exactly correspond with each other, we have been enabled to form the *Table of Evaporation* which accompanies the instrument, with those before mentioned, and which, we have no doubt, will answer the intention of the practitioner ; having been formed with all the accuracy and precision of which the nature of the business would admit, and which a continued application of it, in our own practice, has sufficiently confirmed.

That

That these experiments have not been attended with all that correspondent exactitude which philosophical precision requires, is not to be wondered at, when we consider the dispatch necessary in actual business, and the unavoidable irregularity of those dimensions on which our calculations must necessarily be founded.

In the first place, if the guage of the underback be not very correct, and its contents always dipped with the greatest nicety, the quantity of wort, and, of course, the sum of its fermentable matter, must be wrong, and all calculations arising therefrom must be erroneous *ab origine*.

Secondly, if the quantity in the underback be perfectly ascertained, and the assay-jar, containing a specimen of the wort, be imperfectly or not at all covered, as there will be, in that case, an evaporation from the latter *, which does not take

* From some cursory observations made on this subject, it appears that the difference between a covered and an uncovered jar, is about 0.75 per cent,

take place, and therefore is not accounted for in the former, the real gravity of the wort, calculated from its condensation only, will be wrong represented by it, and consequently cause another error in the sum of the fermentable matter produced.

Thirdly, supposing these particulars to have been attended to, with all imaginable care, the correspondence between the actual and the calculated aggregate of the fermentable matter may not be correct, from the unavoidable retention of a part of the wort in the pump, which conveys it from the under-back to the copper; from some small quantity which may remain in the latter, intermixed with the few hops which will generally be left at the bottom; from the want of time for the whole of the wort to be effectually

cent, in a wort of 30 pounds per barrel and upwards; above 1 per cent, in a wort of half that density; and 3 per cent, in one of 5 pounds per barrel,

drained

drained from the hops; and from a quantity of wort which may, and frequently does, remain in the hop-back, retained by the irregularity of the bottom, the feeds and such parts of the hops as have passed through the false bottom, or by the back itself not being set with a proper current towards the part where it discharges the wort into the cooler.

Fourthly, should none of these obstacles intervene (which can scarcely happen), the several proportions of the whole volume, which worts of different densities evaporate, may not always correspond, with philosophical accuracy, to the notations in the table; because the exposure of a larger surface will produce a more copious evaporation in a wort of equal volume and density, than that of a less; and even a strong current of air passing over it, will have a similar effect, by ruffling the surface, and thereby carrying off a larger portion of the aqueous particles than would have escaped, had it remained in a state of quietude. From a few observations made

upon

upon the difference of effect produced by the different evaporations of the same wort in an assay-jar and in the cooler, it appears that the latter, in many cases, increases the gravity 2 pounds per barrel.

Lastly, the difficulty of ascertaining the exact quantity of wort, and consequently of making an accurate calculation of the fermentable matter it contains, by taking a guage in the coolers, is not the least of the obstacles to be encountered in this business. In large utensils, where a volume of 20 barrels of wort does not, perhaps, lie more than an inch deep in the cooler, without particular care, there is a hazard of making an erroneous estimate of 1 to 2 barrels in that quantity, by dipping, or taking the depth only; for if the rule or guage made use of be perfectly dry, and the wort cold, as it should be at the time of taking the gauge, the surface will bend, as it were, inwards, following the immersion of the rule, so as to make a visible concavity round it; and if taken out then, the

the part wet with the wort will sometimes be near one-tenth of an inch less than its real depth. On the contrary, if the rule be moist, the wort, attracted by the moisture, will ascend upon the rule as much above the level of its surface, as, in the former case, it was below it.

A due attention having been paid to these several particulars, in forming the *Table of Evaporation*, we have no doubt but its judicious application will ensure to the practitioner the desired success.

To apply it, in practice, we must invert, in some degree, the experiments on which it is founded, and by laying down its proportions as certain data, thence proceed to the calculation of the specific gravity finally required. For instance, had it been required to produce from the first wort, in the foregoing example, a length productive of the final specific gravity of 34 pounds per barrel, we must have proceeded to calculate the specific gravity it ought to have, at the point of being turned out of

of the copper, and by occasionally taking out a specimen, cooling, and trying it, during the boiling (in the manner hereafter particularized) we should have been able to have turned it out in that exact state which would have produced the desired effect. The calculation is thus made:

31.47 Barrels of wort in the under-back,	}	889 lbs.
at 28.5 pounds per barrel — —		
Extract of 300 pounds of hops — —		30 —
Deduct for 5 barrels of wort imbibed by	}	170 —
the hops, at 34 pounds per barrel —		
Net fermentable matter remaining —		749 lbs.

Then divide 749 by 34, the gravity to be produced, and the quotient will be the final quantity of the wort at that specific gravity, viz. 22.0 bar.

Add the amount of the evaporation,	}	1.67 —
in the proportion of 7.6 per cent *,		
which on 22 barrels is — —		

Total — 23.67 bar.

* This is the proportion which a wort of 34 pounds per barrel will have evaporated, according to the *Table of Evaporation*; therefore, as 100 is to 7.6, so is 22 to 1.67, as above stated.

Which

Which is the quantity of wort in the copper, at the time of its being turned out. This divided in 749 pounds, the net sum of fermentable matter, gives 31.64 pounds, indicating the specific gravity the wort ought to have had at the above mentioned period, in order to have produced 34 pounds per barrel in the cooler.

This rule is general, and may be applied to all lengths, adopting only the proportion indicated in the *Table of Evaporation*, as corresponding with the specific gravity intended, instead of the proportion here adduced.

As there may be some, however, who may wish to avoid all calculation, as much as possible, and who might prefer a rough system and random principle, if calculated to save time, and come near enough the truth for general practice, we endeavoured, from a comparative view of our continued experiments hereon, to accommodate those of this description with something in their own way. For having observed, in the

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example

example before us, that our first wort gained 2.49 pounds per barrel in gravity, by its evaporation from the copper to the gyle-tun; that our second gained 2.04 pounds by the same means; and that our third increased only 1.58 pound, from a similar cause; we immediately concluded that certain rude principles might be established for the purposes above alluded to, sufficiently satisfactory for the mere man of business; and accordingly, after duly digesting the several results of our own long practice, we sketched out the *Table of the increase of the gravity of Wort, occasioned by evaporation in the cooler*; by the adoption of which, the careful practitioner will not be subject to an error of more than a small part of a pound per barrel, in his intended gravity. In case of this adoption, nothing more is necessary than to deduct from the intended specific gravity, the corresponding increase of gravity in the table, and the remainder will be that specific gravity the wort ought to have when

turned

turned out of the copper. For instance, in the table against 34, is the sum 2.40, as indicating the increase of gravity, which being deducted from 34, the gravity intended, the remainder, 31.6, shews the specific gravity of the wort in the copper, which is only a difference of 0.16 less than that indicated by the more accurate calculation of the table before recommended*.

In order the more expeditiously to cool the specimen of wort taken out of the copper, for the purpose of noting its specific gravity, we caused the *Refrigerator* to be made, already described, the application and use of which being hereafter particularly treated of, we shall proceed to the consideration of the wort in the coolers, preparatory to its being submitted to the action of fermentation.

* Since writing this article, the table has been collated with, and corrected by the table of evaporation, so that it may be adopted with as great accuracy as actual practice can attain to, as will appear in the following section.

SECTION IV.

Of forming AVERAGE GRAVITIES, in order to produce the certain foundation of UNIFORM STRENGTH.

THE first wort, in the above-quoted example, being cool, we took the gauge and specimen, and found the quantity and gravity to be as before mentioned. Had this been fermented alone, this simple process would have been sufficient to have indicated its quantity and quality ; but as other worts were to be added to it, our experiment thereon was not final. We, therefore, proceeded in like manner with the second wort, and making a supposition that these two only were to be fermented together, we demanded the average gravity of the commixture. To solve this we added 736.37 pounds, the net fermentable matter of the first, to 561, the net fermentable matter of the second, the sum of

of which was 1297.37 pounds.—We then added 21.5 barrels, the quantity of the first, to 22 barrels, the quantity of the second, and dividing their sum (43.5) in 1297.37, the sum of the fermentable matter, the quotient, 29.82, shewed the average specific gravity required.

In like manner we added together the several net aggregates of the fermentable matter of all the three worts, the sum of which, 1635.62 pounds, being divided by 64 barrels, the sum of their several quantities, we found that 25.55 pounds per barrel (the quotient) was the average specific gravity of the whole gyle.

To have considered either of these averages as a standard, and to have endeavoured to produce it accordingly, we must have recurred to some of our former calculations on this subject. In the first case, supposing it to have been intended that the two first worts should have been fermented together, and that 29.82 pounds per barrel was the average gravity required,

quired, we should have suffered the first wort to have been boiled its appointed time, without having examined its gravity till in a proper state in the cooler; having then found it to be 34.25 pounds per barrel, we should have proceeded to consider how far the second wort of 29.4 barrels, at 17.6 pounds per barrel (at that time in the copper) should be evaporated, so as to have produced the average intended. For this purpose, we should have made a supposititious estimate that the two worts would be finally of equal quantities, and thence multiplying 29.82, the required average, by 2, and from the product 59.64, deducting the gravity of the first wort 34.25, we should have discovered that 25.39, the remainder, was the required gravity of the second wort; but the quantity of both worts not being equal, this gravity is supposititious, serving only to estimate therefrom the amount of the fermentable matter imbibed by the hops, in order to ascertain the net remainder,

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preparatory

preparatory to the calculation of the true specific gravity required; whence, according to the manner just inculcated, we should have proceeded to have calculated the gravity it ought to have on being turned out of the copper, finally to produce that required gravity. For example,

In the under-back 29.4 barrels at 17.6 = 517.4 lbs.

Add, Sum brought in by 5 barrels of the first wort remaining in the	}	171.25 —
hops, at 34.25	— —	

688.65 —

Deduct, Sum retained by the hops with 5 barrels of this wort, cal-	}	126.95 —
culated at 25.39	— —	

Apparent net aggregate 561.7 lbs.

Add, Net aggregate of the first wort	}	736.37 —
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Total 1298.07 lbs.

This sum being divided by the required average, 29.82, the quotient 43.53, is the number of barrels of which the two combined worts are to consist; deducting from this 21.5, the number of barrels in the first wort, the remainder 22.03, is the final number of barrels in the second;

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which number divided in 561.7, its apparent net aggregate of fermentable matter, shews the required final gravity of the second wort to be 25.49 pounds per barrel.

Then, to the final quantity of wort in the cooler 22.03 barrels.

Add, the amount of the evaporation,	}	1.91
in the proportion of 8.7 per		
cent, (as per table) which on		
22.03 barrels is		

And the total quantity of wort, at	}	23.94 barrels.
the time of being turned out of		
the copper, is		

Dividing this in 561.7, the apparent net aggregate, shews the specific gravity of the wort in the copper to be 23.46 pounds per barrel. Or, pursuing the short method before mentioned, the calculation would have run thus:

Specific gravity required	—	25.49 lbs.
Deduct, increase of gravity by evaporation	2.06	—
Gravity of the wort in the copper		23.43 lbs.

The difference in these two calculations, respecting the gravity of the wort in the copper, being only 0.03 per barrel, it is a natural

natural inference that for general practice, the latter, unscientific as it appears, will be preferred, for the sake of ease and expedition.

We come now to the real state of the brewing before us; *i. e.* the three worts being intended to produce one uniform liquor, by being blended and fermented together, our attention was directed to the certain means of producing the average gravity required for the whole gyle, on the principles here laid down.

Premising that 25.55 pounds per barrel was the average gravity, we paid no regard to the gravity of the two first worts in the copper, but suffering them to boil their proper time, we made the necessary experiments on them in the coolers, and, according to the calculation just adduced, found their average gravity to be 29.82, as before mentioned. This we considered as the average of two-thirds of our whole length, and that the last wort was of course to supply the remaining one-third. We therefore

therefore multiplied 25.55, the required average gravity, by 3, the number of the worts, and the product was 76.65; from which deducting 59.64, the product of the average gravity of the two first worts, multiplied by their number, 2, and the remainder 17.01; shewed the supposititious gravity of the third wort, on a presumption of its quantity being the one-third part of the whole.

We then pursued our former method of calculation to find out its true, final specific gravity, and thence to deduce the gravity it ought to have in the copper, in order to produce the said final specific gravity in the cooler, *viz.*

In the under-back 30.26 barrels at 9.25 = 279.9 lbs.

Brought in by 5 barrels of the second wort remaining in the hops, at 25.5

127.5 —

407.4 —

Retained by the hops, with 5 barrels of this wort, calculated at 17.01

85.05 —

Apparent net aggregate 322.35 —

Add, net aggregate of the two former worts 1297.37 —

Total 1619.72 lbs.

Which

Which total divided by 25.55, the required average gravity, shews 63.4 to be the number of barrels contained in the whole three worts; from which deduct 43.5, the contents of the first and second, and the remainder 19.9, is the final number of barrels in the third wort; which number being divided in its net fermentable matter 322.35, gives 16.2 pounds, the true specific gravity required.

Then, to the final quantity of the wort in the cooler ————— 19.9 barrels.

Add, the evaporation (as per table) } 2.08 —
of 10.5 per cent, which on 19.9 is }

And the total quantity of wort, }
at the time of being turned } 21.98 barrels.
out of the copper, is }

Which sum being divided in 322.35, the net fermentable matter, indicates the specific gravity of the wort in the copper, as above, to be 14.66 per barrel; which, by the short system before referred to, would have appeared thus :

Specific gravity required ————— 16.2 lb.

Deduct, increase of gravity by evaporation 1.57

Gravity of the wort in the copper ————— 14.63 lb.

This

This again exhibits an erroneous difference of 0.03 per barrel, from the former calculation; and this difference, as we have before suggested, will most probably be dispensed with, in the hurry of business, for the sake of the dispatch necessary in the general process of brewing; nor, indeed, is a nearer approach to mathematical certainty to be generally expected, in a business conducted on so large a scale as that of the brewery, for reasons before explained *.

Had two of these worts been boiled together, a practice sometimes adopted, nothing more would have been necessary than to have multiplied the quantity of each by its gravity, and by adding the products of both together, to have considered their sum as the contents of one wort, and to have proceeded as above indicated, for the production of the gravity required.

If we compare the result of these calculations with the actual state of the several

* Vide Note, page 131.

worts,

worts, we shall find a little variation, which is not to be avoided. According to the real products of the first and second worts, their average gravity, as above shewn, was 29.82 pounds per barrel, the second being 22 barrels at 25.5; but, by our mode of calculation, the latter being 22.03 barrels at 25.49, the former consequently appeared 29.79 pounds per barrel. In like manner, the real aggregate quantity of the three worts was 64 barrels, whose average gravity was 25.55 pounds per barrel, whilst the calculated quantity was only 63.4 barrels at 25.54 pounds per barrel.

The cause of this small difference (exclusive of the irregular draining of the wort, before treated of) exists in the impracticability of previously ascertaining the precise quantity of fermentable matter finally contained in the latter wort, which alone is to fill up the measure of the calculation, and produce the required average. For instance, we knew that our third wort contained 279.9 pounds of fermentable

fermentable matter; we knew also that the 5 barrels of the second wort, brought into this by the hops, made an addition thereto of 127.5 pounds; and that the then gross aggregate of fermentable matter was of course 407.4 pounds. Could this have remained entire, the calculation would have been simple, and the average certain; but as we were convinced that the 5 barrels of wort thus brought in, would only be displaced by as much of the present wort, so that 5 barrels of this would still be retained by the hops; and as it was indispensable that its specific gravity, at the time of this retention should be ascertained, in order to discover what portion of the fermentable matter would be retained therewith, and, of course, what would remain to be added to that of the preceding worts; we had no other means of obtaining this information, than by establishing a supposition that the wort in question must be, when in the cooler, equal in quantity to one-half of two worts,

worts, or to one-third of three; and that its final specific gravity must consequently be deduced from a supposititious gravity founded on those proportions. Thus, in the example before us, we were under the necessity of supposing the quantity of our last wort to be finally equal to one-third part of the whole, and, as its gross contents were 407.4 pounds, we thence calculated the supposititious gravity of 17.01 pounds per barrel, which reduced the supposed one-third to 0.6 barrel less than it afterwards appeared to be; yet as this uncertain principle has only relation to the quantity imbibed and retained by the hops, it has so little effect upon the general average, respecting either quantity or quality, as scarcely to merit notice; especially as the general practice of the brewery aims at producing the worts as equal in quantity as possible.

These rules and observations having, we presume, sufficiently explained the means of ascertaining average gravities,

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we shall now proceed to point out the end and purpose of their establishment.

SECTION V.

The utility of establishing a STANDARD GRAVITY, as conducive to the forming therefrom an estimate of the VALUE OF BEERS of different qualities.

WERE it in the power of the brewer to dispose of his liquor at a price proportioned to the quantity of malt employed, or rather, according to the portion of fermentable matter it contains, estimated from the price of the malt itself, the application of the instrument, as above directed, would immediately lead to the value of beers of every strength, deduced by the simplest calculation, from their average specific gravities only; but since almost every situation has its established price and strength, which, being entirely local, have no reference or relation to the prices or qualities of the beers of other places,

places, nor are scarcely ever to be regulated by the cost of the materials themselves, it will be necessary to estimate the local value of beers of different qualities, by the relative proportion which the standard gravity of the wort bears to the obtainable price of the liquor which experience has shown to be producible from that standard. Thus, if it were required to brew beer of a different quality, to accommodate different consumers, the required strength being once known, we have then to calculate, from the general standard gravity, the price at which it should be sold, in order to be proportionably beneficial with the sale of the standard liquor; or, the price being limited, we have in that case to discover what strength must be produced for that price, to be beneficial in a like relative proportion. For instance, supposing 25 pounds per barrel to be the general standard alluded to, and that the beer produced from it sold for 25 shillings per barrel, clear of

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the duty, which should not be included, it is an obvious inference that the product of any other gravity would be proportionably advantageous, if sold at the rate of one shilling per barrel for every pound of fermentable matter it previously contained. Hence, if forty pounds per barrel were the required gravity, the price ought to be forty shillings, exclusive of the duty; or if the obtainable price were limited to thirty-six shillings, or any other specific sum, the proportionate gravity or strength would be thirty-six pounds per barrel, or such other gravity as should be correspondent to the specific price. In like manner, were the same standard to be estimated at a different rate, a similar proportion must take place. Thus, premising the standard price to be but twenty-three shillings per barrel, exclusive of the duty, we should say, for a required gravity of forty pounds per barrel, as twenty-five pounds, the standard gravity, is to twenty-three shillings, the
standard

standard price, so is forty pounds, the required gravity, to 36.8 shillings per barrel, the required proportionate price. Or, in the instance of the price being given, supposing it to be thirty-six shillings per barrel, we should then say, as twenty-three shillings, the standard price, is to twenty-five pounds, the standard gravity, so is thirty-six shillings, the given price, to 39.13 pounds per barrel*, the required proportionate gravity.

The propriety and utility of these calculations will be obvious to every one who is occasionally engaged in the production of strong beers intended to bear different prices; and even in that of small and table beer, they will not be undeserving of attention.

According to our first ratio, we should learn, that if we suffered our small beer to be of a gravity exceeding six pounds per

* It may be superfluous to remark, that the specific gravity every where mentioned in this article, is that of the wort in the cooler, at a fermentable temperature.

barrel, when sold at the price enjoined by law, it would be a less advantageous branch than that of strong; and were a table-beer to be demanded, we could immediately calculate the gravity it ought to have, as above inculcated, proportioned to the price we should obtain for it; and that with a degree of precision to which the usual vague mode of estimating so many barrels per quarter, can in no wise bear a comparison, and which must totally put to shame that more vague and barbarous appeal to the palate, authorised by the board of excise, or assumed by its officers, in characterising or determining the quality of worts, as a rule for their conduct in the charge of the duties; or rather, as a means of detecting frauds, or preventing impositions upon the revenue.

SECTION VI.

Of the attenuation of the fermentable matter, or an attempt to ascertain the STRENGTH OF MALT LIQUORS, by a comparative view of their specific gravities, prior and posterior to the action of fermentation.

IN order to ascertain how far the apparent *strength*, or the *inebriating quality* of beers, fairly produced by fermentation, had a relation to the quantity of fermentable matter attenuated by that action, we proceeded to examine several different kinds of malt liquor, whose previous or average gravity had been duly noted, and the result of that enquiry was as follows:

0.8 I	—	0.8	—	—	2.92	—
0.6 I	—	0.6	—	—	0.40	—
0.4 I	—	0.4	—	—	2.72	—
0.2 I	—	0.2	—	—	2.42	—
0.0 I	—	0.0	L ₃	—	2.02	Strong

Strong Ale.

N ^o .	Gravity of the wort in a fermentable state.	Gravity of the beer when transparent.	Gravity left, or amount of the fermentable matter attenuated.
1	— 42.0 —	— 18.6 —	— 23.4 —
2	— 41.7 —	— 22.5 —	— 19.2 —
3	— 41.0 —	— 20.8 —	— 20.2 —
4	— 40.6 —	— 18.1 —	— 22.5 —
5	— 40.0 —	— 21.6 —	— 18.4 —
6	— 39.0 —	— 18.5 —	— 20.5 —
7	— 38.3 —	— 17.8 —	— 20.5 —
8	— 36.7 —	— 17.2 —	— 19.5 —
9	— 36.0 —	— 12.5 —	— 23.5 —

Common Ale.

1	— 32.3 —	— 13.9 —	— 18.4 —
2	— 28.0 —	— 5.1 —	— 22.9 —
3	— 27.7 —	— 6.9 —	— 20.8 —
4	— 27.0 —	— 8.5 —	— 18.5 —
5	— 25.2 —	— 11.5 —	— 13.7 —
6	— 24.4 —	— 9.7 —	— 14.7 —
7	— 23.5 —	— 7.6 —	— 15.9 —

Porter.

1	— 29.5 —	— 8.3 —	— 21.2 —
2	— 26.0 —	— 6.5 —	— 19.5 —
3	— 25.5 —	— 6.0 —	— 19.5 —
4	— 24.5 —	— 6.5 —	— 18.0 —
5	— 23.3 —	— 5.3 —	— 18.0 —

Table

Table Beer.

No.	Gravity of the wort in a fermentable state.	Gravity of the beer when trans- parent.	Gravity lost; or amount of the fermentable matter attenuated.
1	19.4	7.5	11.9
2	9.4	2.7	6.7

On taking a comparative view of these specimens, and observing that the amount of the attenuation did by no means correspond with the original gravity, or that different worts were not attenuated in proportion to their respective gravities, we were led to conclude, that all our former conjectures on this subject were erroneous; especially when we considered that two liquors equally attenuated, though originally of very different gravities, had apparent strength, or inebriating effects more nearly proportioned to their gravities, than to the amount of the attenuation.

To be assured of this, we put one beer gallon of the *strong ale*, No. 5, into a small

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still

still, and having drawn over one wine-quart (before the completion of which, the liquor which came over had, for some time, been mere water), we found, by experiment, that the strength of the liquor thus distilled, was 36.4 parts of 100 proof spirit; or, that the composition consisted of 36.4 equal parts of proof spirit, and 63.6 of water. Then saying, if one gallon of ale produce 0.364 quart of proof spirit, 36 gallons will produce 13.1 quarts; by which we discovered, that an attenuation of fermentable matter to the amount of 18.4 pounds per barrel, produces 13.1 quarts, wine measure, of proof spirit.

We then took one gallon of the weakest *porter*, (No. 5) the amount of whose attenuation was 18 pounds per barrel, and distilling, in like manner, one wine-quart, its strength appeared to be 37.3 parts of 100 proof spirit, which was in the proportion of 13.4 quarts per barrel. So that, in this experiment, the attenuation
of

of 18 pounds per barrel, produced 13.4 quarts of proof spirit; a quantity rather exceeding that of the former experiment, though the attenuation was somewhat less; which we are inclined to attribute to some little difference in the accuracy of conducting them; the former having boiled over at first, which might occasion some loss of spirit, though the liquor thus thrown over was carefully returned into the still.

Several other distillations which we made, with various success, served to convince us, that though the quantity of spirit produced, did not, in our experiments, exactly correspond with the amount of the attenuation, in the ratio above quoted; yet the relation between them was sufficiently near to warrant our opinion, that, by a distillation conducted on a larger scale, and with measures more philosophically correct, it will be found that every pound of fermentable matter [attenuated by the action of fermentation, will

will produce the same quantity of proof-spirit, by distillation, whether that attenuation has been effected in a strong wort of 40, or a weak one of 10 pounds per barrel.

Our present experiments, which we must acknowledge to have been too imperfect and inaccurate to justify our founding a system upon them, do indeed tend to a suspicion that the attenuation of weaker worts, produces a somewhat greater portion of spirit than that of the stronger. Those which we have noted are the following:

No.	Gravity of the wort.	Attenuation.	Spirit produced.
1.	— 40.0 lbs. —	— 18.4 lbs. —	— 13.1 quarts. —
2.	— 23.3 —	— 18.0 —	— 13.4 —
3.	— 25.2 —	— 13.7 —	— 11.6 —
4.	— 19.4 —	— 11.9 —	— 9.7 —
5.	— 9.4 —	— 6.7 —	— 6.5 —

Now if we establish the second experiment as a standard (having been the best conducted) and calculate the proportionate quantity of spirit producible from the several attenuations of the other experiments, they will stand thus:

No

N ^o .	Gravity.	Attenuation.	Spirit produced.	Spirit producible in the ratio of the second experi- ment.
1	40.0 lbs.	18.4 lbs.	13.1 quarts	13.7 quarts
2	23.3 —	18.0 —	13.4 —	13.4 —
3	25.2 —	13.7 —	11.6 —	10.2 —
4	19.4 —	11.9 —	9.7 —	8.9 —
5	9.4 —	6.7 —	6.5 —	5.0 —

From this view of the spirit actually produced, and the several proportions producible, according to calculations made from the quantity obtained by a very accurate experiment, it is evident that there is a correspondent relation between the portion of fermentable matter attenuated, and the spirit produced by fermentation, entirely independent of the original gravity of the wort, or the apparent strength of the beer, though that relation, as not immediately necessary to our purpose, we have not as yet had leisure to examine, with that accuracy and precision requisite to establish so novel a discovery.

In the investigation of this subject there is, however, a circumstance presents itself

self to our consideration, of which we were not at first aware ; and that is, the conviction, from these experiments, that *the apparent STRENGTH of malt liquors, or that INEBRIATING EFFECT which they produce upon the animal frame, does not entirely consist of SPIRIT.*

To prove this, we need only advert to the experiments just noticed, where we shall see that ale so very strong as, that produced from a gravity of 40 pounds per barrel, yielded no more proof spirit (the produce being strictly less), than the weak porter in the second experiment, of 23.3 per barrel ; though the same person drinking an equal quantity of each, would have found their effects to have been powerful, rather in proportion to their respective gravities, than to the quantity of spirit producible from them. Indeed, if we consider the small portion of spirit contained in this strong ale ; that it is not the one twelfth part of the whole ; and that yet this ale (of the Burton kind) would

would produce as potent an effect upon the drinker, as the same quantity of spirit and water, consisting of one fifth, or at least one-sixth part of the former; we shall be convinced that there is another principle in malt-liquors (if not in all fermented liquors) besides that of *spirit*, which contributes to that inebriating quality to which common usage has affixed the name of *strength*.

If we suppose this strength, in the present case, to be equal to a commixture of spirit and water containing one-sixth part of the former, we shall then find that this new principle is equal in effect to the quantity of its concomitant spirit; for supposing each to be one-twelfth part, the sum of them both will be just equal to the quantity of real spirit in the commixture above mentioned, as their effects are equal; and till we have a better clew to direct our judgment herein, than the sensibility of the palate, or the strength of the brain, we must be content with probable

bable conjecture, and rational hypothesis for our guide.

The most natural supposition which occurs to us, on the present occasion, is, that the principle here alluded to is the *gas* or *fixed air*, produced by, and inherent in all fermented liquors, so long as they contain the least essential particle of their original composition, or of those constituent parts which form their value; and as the production of *inflammable spirit* is the criterion of vinous fermentation, and as that fermentation is always productive of the *fixed air* we are here treating of, it is a most probable conjecture that their production being concomitant, *ab initio*, so is their existence inseparable, so long as their last and least characteristic particle remains.

That they are thus constantly and inseparably attendant on each other, so long as the liquor which produced them merits our observation, may be easily demonstrated. Simple distillation proves the existence

istence of the *spirit*, and the least motion or close confinement of the liquor shews that of the *fixed air*, by its incessant attempts to escape. Beer newly drawn from the cask, or agitated in a glass after remaining in a state of quietude, having by either means the coherence of one particle to another disturbed, is deprived of a considerable portion of air, which is thence set at liberty, and its escape is visible to the eye. The same effect is observable after beer has been some time confined in a bottle, by which means the perpetual tendency of the air to escape is prevented; for no sooner is the cork drawn than the air rushes with impetuosity from every part, to the surface, where its escape is as sensible to the smell, as its progress thither is visible to the eye.

Its existence, as air, cannot be more incontrovertibly proved; and that it flies off with, or rather before the spirit, in distillation, there is not less doubt. The smell discovers its avolation and escape before

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the spirit is sufficiently rarefied to rise; for being more volatile it must, of necessity, come over first; and the vapidty and nauseous flavour of the caput mortuum which remains, after the spirit is drawn off, seem to indicate that the fixed air has taken its flight with its companion, though the latter, only, is arrested in a palpable form.

Having thus demonstrated that fixed air is the constant attendant of the spirit produced in malt-liquors, it remains for us to endeavour to investigate the causes of its irregular produce, and to examine its claim to those effects which are ever consequent to that quality generally termed *strength*.

Though in the instance just now ad-
duced, we have supposed the fixed air and
the spirit to be equal, from observing their
united effects upon the drinker of the
liquor which contained them, and from a
comparison of similar effects produced by
a liquor of definite strength, we do not
thence

thence mean to insinuate that they are always equal in quantity or effect, the contrary of which is evidently the case; for the different proportions of either can only result from accidents dependent on the previous strength or gravity of the wort, the mode of conducting the business of fermentation, and the manner of preserving the fermented liquor:

With respect to the former particular (the gravity of the wort) we shall be convinced of the inequality of the production of these two principles, by attending to the few experiments above noted. In the first and second we see the quantity of spirit actually produced was nearly equal, yet the gravities of the worts were different in a ratio of 3 to 5, and the inebriating effects of the liquors when fermented were nearly different in a like proportion. Hence, taking it for granted that our first experiment contained fixed air equal in effect to the spirit which it produced, (*i. e.* one-twelfth part of the whole) and establish-

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ing that as a standard, we can calculate the the real strength or inebriating quality of the second, according to the proportion of its previous gravity, by saying, as 40, the gravity of the first, is to 23.3, the gravity of the second, so is 12, the supposed portion of fixed air in the first, to 7, the proportionate quantity of fixed air in the second. Then adding the spirit producible, according to the fermentable matter attenuated, to their respective portions of fixed air, and the strength of the two liquors will stand thus :

First experiment, from the strong Ale, No. 5.

Spirit	-	12
Fixed air	-	12

Inebriating quality - 24 parts of 144.

Second experiment, from the Porter, No. 5.

Spirit	-	12
Fixed air	-	7

Inebriating quality - 19 parts of 144.

• The number of quarts in a barrel.

Hence

Hence we see that the inebriating quality of the second exceeded the proportion of its gravity, merely by an extra production of spirit, the consequence of a different mode of conducting the fermentation; for had the spirit produced been in the ratio of its gravity, the inebriating quality would have only been 14, instead of 19 parts of 144; for, as 40 is to 23.3, so is 24 to 14.

If we try the third experiment by the same rule of proportion, we shall find that it falls short of the second, though from a wort of superior gravity, from the same cause which operated in favour of the latter, in the production of the extra portion of spirit just mentioned. For example, as 40, the gravity of the first experiment, is to 25.2, the gravity of the third, so is 12, the supposed portion of fixed air in the first, to 7.5, the proportionate fixed air in the third. Then estimating the producible portion of spirit (10.2 wine-quarts) at 9 quarts beer-measure, the strength of the beer will be thus estimated:

blue

M 2

Third

Third experiment, from the common Ale, No. 5.

Spirit - - 9

Fixed air - - 7.5

Inebriating quality - 16.5 parts of 144.

Yet this, though it fell short of the strength gained in the second experiment, exceeded the ratio of the first; for, according to that proportion, it would have been little more than 15.

We are hence led to the consideration of the second operating principle in this business; *i. e.* the mode of conducting the fermentation, which has a very considerable influence on the production of both the fixed air and the spirit.

In the first experiment, the great strength or density of the wort requiring a greater force in the fermenting principle than was admissible in that particular practice which was to be productive of the qualities required in that particular liquor *, the portion of spirit was of course less than it might have been, if a stronger ferment

* Ale, of the Burton kind. How used

could have been consistently adopted. On the contrary, the second experiment having had all the auxiliary force which can be applied to a fermentation intended to produce a potable vinous liquor, the attenuation of the fermentable matter exceeded three-fourths of the whole, whilst that of the first did not proceed much further than nine-twentieths, the consequence of which was, that extra-quantity of spirit observable in the second. And that the quantity of fixed air in the latter was not equal to that of the former may be attributed to the extraordinary force of the fermentation, which carried off a great portion of it during its action; for it is not to be doubted that fermentation, conducted in a certain powerful manner, and carried to a certain length, will so far deprive the liquor of its fixed air as to render it scarcely discernible. It may, therefore, be established as a principle, that *the quantity of spirit produced by an imperfect fermentation is less than its fixed air; and that a fermentation carried to its utmost length, dissipates its fixed air in*

proportion as it increases its quantity of spirit.

A corroborating circumstance, in support of this principle, occurs in the deficiency of yeast, observable in consequence of an imperfect fermentation; for as wort abounds in dormant, inactive air, enveloped in the fermentable matter, it is no sooner put into action than it seeks to disentangle itself, and in its escape becomes a doubly operative principle; viz. generative, in the production of spirit; and excretory, in the separation of the mucilaginous parts of the fermentable matter, which assumes the form of yeast; whence the more it is dissipated, the greater is its produce in these two articles, and *vice versa*.

The last particular which engages our attention, on this occasion, is the effects resulting from the manner of preserving the liquor. That this has an influence on the apparent strength will be generally acknowledged; but whether it is to be ascribed

ascribed to an additional production of spirit, or to an increase of fixed air, or to a participation of both, we cannot take upon us to demonstrate, not having yet had opportunity to apply the still to the same liquor, at different periods, and in different modes of its preservation. We are, nevertheless, inclined to the opinion that the generation of the fixed air, as more obvious to the senses, is the more probable cause of that difference in strength distinguishable in malt-liquors kept in bottles, though we do not mean to insinuate that there is not a similar addition to the spirit, when kept in casks, nor a partial addition of each in both cases. What we wish to demonstrate is, the certainty of the fact, that fixed air is generated posterior to the completion of vinous fermentation; after the liquor is become potable; and even after accident or negligence has destroyed some of its most valuable qualities, and rendered it unfit for use.

It is well known that during fermentation, the production of the fixed air is so abundant, that were not means provided for its escape, the strongest vessels could not contain it; and as the force of that action abates, the avolation of the air proportionably decreases, so that when the liquor is in a quiescent state, the escape of the air is not perceptible. Yet after the cask is closed, and it finds no other vent than through the pores of the wood, we frequently perceive it collected in such force as to rush out with great violence so soon as an aperture is made in the cask, and even to force a considerable quantity of liquor with it, to the height of five or six feet.

The same effect is observable on a change of the temperature of the external air, from cold to warmer, and that after the liquor has been for some months apparently quiet; for in this case, the fixed air being rarefied, escapes in greater quantity

tity, and produces effects similar to those just described.

A further proof of the continual production of this air, is the *recovery* and *melioration* of beers which have been quite vapid and undrinkable, by the simple operation of bottling only. The cause of vapidity being nothing more than the total escape of the fixed air at that time generated, and the beer being thus deprived of its vital principle, can recover by no other means than those of an effectual prevention of all further escape, till such a portion of fixed air is again generated as will supply the place of that which is lost. In that case, bottling is the most efficacious remedy, particularly if the bottles are placed in a temperature somewhat warmer than that wherein the cask was, from which it was drawn. By this means the liquor, being still generative of fixed air, is again replenished with it, which effects its *recovery*; and that generative principle continuing still active, the
air

air becomes abundant (all escape being prevented) which is productive of *ripeness*, commonly so termed, or that *melioration* above alluded to.

It now remains for us to endeavour to fix some criterion by which we may be assured that the fixed air thus generated, is a component part of the strength of fermented liquors. In this having unfortunately no better guide to direct our enquiries than the vague discrimination of the senses, we must be content to reason from analogy, till some further chemical analysis shall lay a foundation capable of supporting a system established in mathematical certainty.

A judgment may be formed on this subject, by comparing the different effects of equal quantities of the same beer, one part taken from the cask, when it is in a quiet state, and the other from a bottle, when ripe and full of fixed air; in which case, the apparent strength of the latter will be found so far to exceed that of the former,

former, as scarcely to need any other argument in favour of the air we are treating of.

Of the powerful influence which this, as an inebriating principle, has upon the animal frame, we can speak from experience, and perhaps no instance is more strongly in point than the following: Upon some exhausted, refuse raisins, from which wine had been just made, we poured some water, and after letting it remain on them a short time, we let it drain off, when it was so slightly tintured, as to render it a matter of doubt whether the water had imbibed a sufficient portion of the qualities of the raisins to produce the most humble imitation of wine; for it was not discoloured, but its taste did just impress a very faint sensation of sweet upon the palate. It was, however, suffered to remain till it became somewhat transparent, when it was bottled, for the sake of experiment, without having exhibited any signs of fermentation;

tion; and after some of it had remained two years, on being poured into glasses, it exhibited every appearance of Champagne, filled, sparkled, frothed, and threw up a brilliant spray exactly imitating that admired liquor. Its effects were not less extraordinary; for they were exhilarating in a degree nearly equal to those of Port wine, though we are convinced there could not have been a portion of spirit in the liquor equal to one-fiftieth part of the whole.

It may also be observed, that bottled cyder, fretting wines, &c. produce similar effects from the same cause.

The gas, or fixed air resulting from the effervescence occasioned by the commixtion of acid and alkaline substances, is of this kind, as is evinced by the common mode of impregnating water therewith, in order to imitate that of Pyrmont, the apparatus for which is in the hands of most polite people. The effects of this air, without a particle of spirit, is a transient exhalation

ration (we will not call it *inebriation*;) which passes off so much the sooner, on account of the total want of spirituous substance, and generative principle, in the fluid which produced it, to support its continuance.

To the same influence may be attributed the complaint of experienced topers, that they are sooner intoxicated by drinking different liquors, than they should have been had they drunk the same quantity of one sort, though equally strong. If mere spirit be the only efficient cause of intoxication, this commixtion of liquors could not produce the effect complained of; for, in that case, it would be indifferent what liquor becomes the vehicle of the spirit, so long as the quantum is the same. But this effect seems to originate from the probable commotion and effervescence of the heterogeneous commixture in the stomach, producing or setting at liberty a quantity of fixed air, which
rising

rising into the head, is the assistant cause of their complaint.

On the contrary, a sensible diminution of the inebriating effect is observable in malt-liquors grown vapid or flat, agreeably to what has been before suggested on that subject. And that the cause of this diminution is the same which occasions their vapidty, (*i. e.* the loss or escape of their fixed air) is evident from this consideration; that the difference in effect is producible in so short a time as that of a few hours, during which the exposure of the liquor could not have produced any perceptible diminution of the spirit, though it might completely have effected the escape of the fixed air, that being so much more volatile than the former as to be in a state of perpetual avolation.

If we recur to the sensations immediately consequent to the use of spirituous fluids, we shall perceive that those occasioned by a mixture of spirit and water
are

are different from those which are the effect of strong malt-liquors; the probable cause of which is, that the strength of the former consists of mere spirit, and that of the latter is part spirit and part fixed air. The moment that a compound of spirit and water is taken into the stomach, it occasions a hot or ardent sensation; malt-liquor, on the contrary, excites first a gentle, genial warmth, which improves into a mild glow of the stomach and intestines, and differs from the former in the same degree as the warmth of the sun does from the heat of a fire.

It is not an improbable supposition that this difference arises from the different texture or consistence of the malt-liquor, whose spirituous particles are blunted or sheathed by the farinaceous mucilage with which it abounds; which also enveloping and being the efficient cause of the fixed air, becomes the common medium through which both that and the spirit must act; whence that gentle sensation of warmth

just mentioned, is the first and only effect, till the heat of the stomach has rarefied the air, and thence increased its action and tendency to rise, by which means those consequent sensations are effected. Hence those malt-liquors which are more abundant in fixed air, whether arising from the materials or the process, are softer upon the palate, and milder in their effect than those which have less, though the inebriating quality of both may be finally equal.

These hints on the strength of malt liquors, may suffice for the present; and if they should be the means of exciting the curiosity and exercising the talents of ingenuity to a farther and more effectual enquiry on the subject, the purpose of their publication will be fully answered.

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SECTION VII.

PRACTICAL DIRECTIONS *for the general Application of the Instrument, in order to effect the Purposes before treated of.*

HAVING already pointed out the particular utility of the *Saccharometer*, in every particular stage of the brewing process, it may seem superfluous, perhaps impertinent, to a clear head and a comprehensive understanding, to enter into a detail of circumstances sufficiently indicated or inferred in the preceding sections; but since it may not be the lot of every one, who may wish to derive information and advantage from the contents of these pages, to be classed under that description; and as there are some particulars to be inculcated which have not hitherto been fully explained, we chuse rather to hazard the imputation of prolixity and repetition, than that of wanting perspicuity and precision, where beneficial information is in-

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tended

tended on a subject never before committed to the press.

To answer the desired purpose it is necessary to enter into the minutiae of the business, and to indicate the direct manner of effecting the intended information; that every one, by clearly comprehending the *means*, may with certainty obtain the *end*.

The first preliminary step to be taken is the procuring correct tables of the contents of the under-back and coolers; the former indicating the quantity contained in every inch of its depth; the latter pointing out the quantity at every one-tenth part of an inch, and extending to about four inches, deeper than which a wort is seldom laid in the coolers.

A guaging rod is then to be provided, somewhat more in length than the whole depth of the under-back, which rod must be graduated into inches, subdivided into tenths, or at least into fourths, which latter division is in general sufficiently minute for the purposes of the under-back;

back; and where a small rule, divided into inches and tenths, is purposely provided for the coolers, there is no necessity for smaller graduations on the under-back-guage, if wanted for no other use, those being sufficiently near the truth for general practice.

The next thing necessary is a book, containing any number of leaves, of about the size of a half sheet of fool's-cap paper, ruled longitudinally into ten columns, for the purpose of a *diary* or *journal*; in which is to be inserted the particulars of every process, so far as they relate to the subject of which we are treating.

The first column is to contain *the date of the brewing*.

Second, the number of *quarters of malt used*.

Third, the *quantity of hops employed*.

Fourth, the barrels of *wort in the under-back*, the amount of the *expansion* being previously deducted.

Fifth, the *gravity of each wort in the under-back*.

Sixth, *the amount of the fermentable matter extracted in each wort.*

Seventh, *the barrels of cold wort in the coolers.*

Eighth, *the gravity of each wort in a fermentable state.*

Ninth, *the net aggregate of fermentable matter remaining in each wort, at the above period.*

Tenth, *the amount of the fermentable matter extracted from each quarter of malt.*

To these, as matter of not unuseful information, might be added two other columns:

The first, to shew the *specific gravity of the beer* in a state of quietude and transparency.

The second, to indicate the *amount of the attenuation*, or the difference between the average gravity of the wort, and the gravity of the beer in the state just mentioned.

In this journal our process before treated of, would stand thus:

Date,

Materials of Brewing.

181

Date.	Quat- ters of malt.	lbs. of hops.	Wort in underback	Gra- wily.	Ferment- able mat- ter ex- tracted.	Wort in coolers.	Gra- wily.	Net ferm- matter remaining	Ferment- able mat- ter per quarter.	Gravity of beer.	Attenua- tion.
1782.			31.47	28.5	889.0	21.5	34.25	736.37			
			29.4	17.6	517.4	22.0	25.5	561.0			
			30.26	9.25	279.9	20.5	16.5	338.25			
May 16	24	300	91.13	18.52	1686.3	64.0	25.55	1635.62	70.26	11.8	13.75

N 3

Sup-

Supposing this brewing now to be proceeded upon, and that the saccharometer and necessary apparatus are at hand, so soon as the first tap is spent, and the mashing-tun cocks are turned off, preparatory to the second mashing, we take out our specimen in an assay jar, and putting on the cover, place it in the jar-case, before described, premising it to be already charged with cold water; by which means it is cooled, to an assayable heat, by the time the business of mashing is over. At the same time also, we note the heat of the wort with the thermometer, and taking the depth of it, with the gauging rod, we refer to the under-back table of contents, and against the number of inches which is the depth of the wort, we have the number of barrels it contains. But this, as we have before explained, shewing only the quantity of the wort, in its then state of expansion, we make a minute or memorandum of the quantity and heat in any manner, to assist the memory, and so soon

soon as the specific gravity of the wort is found, by the instrument, we have recourse to the *table of expansion*, according to which we deduct the amount of the expansion, correspondent to the heat and density of the wort, from its apparent contents, and enter into the journal only what would have been the real quantity, at 50 degrees of heat, supposing no evaporation to have taken place. Against this sum we immediately place its gravity, regulated by the *table of heat*, and multiplying the one by the other, we find the sum or aggregate of the fermentable matter the wort contains; which sum being then inserted in the next column, the journal appears thus:

N 4

Date.

Date.	Quar- ters of malt.	lbs. of hops.	Wort in underback vity.	Grav- ity	Ferment- able mat- ter ex- traBed.	Wort in Grav- ity.	Grav- ity.	Net ferm- matter remaining	Ferment- able mat- ter per quarter.	Gravity of the beer.	Attenua- tion.
1782			31.47	28.5	889.0						
May 16	24	300									

Proceeding exactly in the same manner with the second and third worts, we insert them, in their turns, immediately under the first, in the proper columns, as shewn in the former example; and adding up the several quantities of the three worts, and the several sums of the fermentable matter extracted, we divide the aggregate sum of the wort in that of the fermentable matter, and the quotient is the average gravity of the raw wort; for instance, 91.1 divided in 1636.3 gives 18.52, the said average gravity; which division is, indeed, of no other use on the present occasion, than by being placed in a line with the quantity, gravity, and aggregate fermentable matter of the whole wort, in a fermentable state, to exhibit a comparative view of these particulars opposed to parallel circumstances in the raw extract, and thence to draw useful inferences not inapplicable to future practice.

It generally happens that all the worts in the under-back are assayed before the first

first wort in the cooler is in a fermentable state, or sufficiently cool to be let into the gyle-tun; in which case the business of the raw extract, or wort, is entirely concluded, before that of the boiled is begun; and that, of course, the one occasions no interruption to the other.

Having finished and duly noted our experiments on this first part of the process, so soon as we find the first wort in the cooler in a proper state to let down, we dip it with our rule, graduated into inches and tenths, as accurately as possible, and take a specimen in an assay-jar. We then refer to the table of contents calculated for this cooler, and noting the quantity correspondent to the depth which it happens to be, we insert it in the next, or seventh column of our journal; just as it appears, because the evaporation has taken place; after which, having found its specific gravity with the instrument, and rectified it by the *Table of Heat*, we note it in the succeeding column, and multiplying the one
by

by the other, insert the product, or net aggregate of fermentable matter remaining, in the next or ninth column, in the same manner as had been done by the wort in the under-back.

The second wort, when in a similar state, is submitted to the same process, and is noted under the first, in the proper columns of the journal, as appears in the former of the preceding examples. Should this, however, not be entirely cool, before it be necessary to attend to the third wort in the copper, it will nevertheless be generally so far advanced towards that state, as to be at an assailable degree of heat; and as the evaporation which takes place within the limits of those degrees, is not very considerable, we may venture to take the gauge and specimen, and make our calculation, in the same manner as if it had been entirely cool.

If, however, in any instance, this wort should not be at an assailable heat, at the time we want to proceed to a calculation

of

of the average gravity, the assay-jar may be placed in the jar-case, to produce that effect. But it is to be remembered, that the jar is to be uncovered on this occasion, that such an evaporation may take place as the jar will admit, though, as we have elsewhere observed, that evaporation would be very inadequate to the effect of the cooler.

This calculation of an average gravity we have before shewn to be effected by adding the net aggregates of the two worts together, and dividing the sum by the number of barrels contained in them both, in order to discover the average gravity of those two; which being considered as the gravity of two-thirds of the intended gyle, we immediately proceed to calculate therefrom, in the manner before inculcated, to what gravity the third wort must be evaporated, in order to produce the average gravity required in the whole. But this business having been already fully explained, in the third and fourth sections

sections of this part, it only remains for us to indicate the mechanical or manual mode of producing the desired effect.

Herein we are primarily to consider how near the previous gravity of the raw wort approaches to the final gravity intended, and according to its approximation to or distance from it, to be earlier or later in our application of the instrument to the boiling wort, that we may not waste our time by unnecessary attention, nor our property, by a careless remissness.

A little experience will direct our judgment in this particular; for, by observing what portion of time is in general necessary to effect any given increase of gravity, we can, *ceteris paribus*, judge so nearly of the time requisite for any other increase, as not to risque an error, especially if we are careful to begin our experiments a little earlier than we suppose it to be absolutely necessary; a precaution not unworthy attention. Thus, if by experience we find that a gravity of 10 pounds
per

per barrel, will be increased to 15, in three hours boiling, it would be advisable to take a specimen and make an experiment, after the wort has boiled two hours and a half; and to adopt a similar precaution on any other occasion.

These particulars being premised, and the time recommended for making the first experiment being arrived, we take the refrigerator, and having fixed on the perforated lid, we plunge it into the boiling wort. As soon as it is full, of which we can judge by its weight, we take it out, remove the perforated lid, put on the whole lid, and immediately immerse it in a pail or tub of cold water of sufficient depth to reach nearly to the top, being careful that none of the water be mixed with the wort, by ruffling the surface, or causing an undulating motion in it, on immersing the refrigerator.

Having now the saccharometer, thermometer, and assay-jar at hand, in about one minute's time, or a little more, the
wort

wort will be in an assailable state. This is best known by slipping off the lid of the refrigerator, and applying the thermometer, at the end of that period; when (if we find the wort at an assailable degree of heat) we immediately pour the wort into the assay-jar, and try the specific gravity with the saccharometer; the whole of which, as we have before intimated, may, without the assistance of extraordinary dexterity, be effected in about two minutes.

If by this experiment we find the wort has not yet arrived at the gravity required in the copper, we suffer it to continue boiling, and repeat the experiment at such intervals as our judgment indicates to be necessary, till we perceive that our intended gravity is produced; at which time the fire is to be immediately damped, or drawn off, and the wort turned into the coolers.

When this wort is also cool, we take the guage and the specimen, and finding its quantity by the table, and its gravity

by the instrument, we insert them ordinally in the seventh and eighth columns of the journal, under those of the preceding worts; and multiplying, as before, the quantity by the gravity, we discover the net aggregate of fermentable matter it contains, which we insert in like manner in the ninth column. Then adding the several quantities of the three worts together, and their several aggregates of fermentable matter, we draw a line, and note their sums in their respective columns; not neglecting to divide the latter by the former, in order to discover the average gravity of the whole, which we insert between the said sums, in the column of gravity.

This being all that is necessary to be done respecting the worts, we divide the gross sum of the fermentable matter produced, by the number of quarters of malt employed, and the quotient shews the number of pounds of fermentable matter extracted from every quarter of malt,

malt, or the intrinsic value of it, which is noted in the tenth column. In the example before us, the fermentable matter is 1686.3 pounds, which divided by 24 quarters, produces 70.26 pounds, the amount extracted from every quarter used.

At this period our journal, at a single view, and in one line, presents us with the following useful information:

1. The materials employed.
2. The gross value of the malt, indicated by the aggregate amount of the extract.
3. The net sum of the product of the materials; the specification of whose value comprises a plain definition of the quantity and quality of the whole wort, in a fermentable state.
4. The specific value of the malt explicitly defined.

If to these particulars we add the two columns above mentioned, in that case we take the first opportunity of obtaining the gravity of the beer when transparent, and note it in the former; which being

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then deducted from the final average gravity of the wort, the difference (inserted in the last column) shews how much of the fermentable matter has been attenuated by the action of fermentation, intimating thereby the force of that operation, and its relative influence on the strength of the beer produced, according to the principles which have lately been the subject of our investigation.

SECTION VIII.

INCIDENTAL CIRCUMSTANCES *in which the SACCHAROMETER may be of considerable Utility.*

WE have already had occasion to point out the use of the saccharometer in ascertaining the value of malts, but there are circumstances attendant on the use of them in brewing, which, not being common, we have not yet mentioned. One of these is that disagreeable accident technically termed *setting the goods*; which is the converting the malt in the mash tun into
6 a pasty,

a pasty, clammy, gelatinous consistence, by an injudicious application of improper heat in the liquor, or water used for mashing, or from some other cause; the concomitant effect of which is a great deficiency in both the quantity and quality the extract, in the detection of which the use of the instrument is singularly advantageous.

The occurrence of this accident *totally* is not, indeed, frequent; but we apprehend that its *partial* appearance is more common than many are apt to imagine. If the brewer knows how much liquor he turns upon the malt, he also knows what quantity of wort he should have in the under-back, if the malt be good, and the process has been properly conducted. Should this fall short in so large a proportion as one-third or one-fourth part, the goods may be said to be *totally* set; if in a less, they are *partially* set.

In either of these cases, if he estimates his loss by the quantity deficient, or attempts to make good the deficiency by a fresh application of water, on a supposition that his wort is strong, in proportion to the shortness of the length, or smallness of the quantity extracted, he is egregiously wrong. The instrument will shew him that not only his quantity is less, but the strength or gravity of the extract is also deficient; from the discovery of which he will be enabled to guard against injuring the reputation of his beer, by a false estimate of its strength, on that occasion, and will be prepared to provide for the prevention or remedy of similar accidents in future; for his loss being accurately ascertained, the discovery will naturally excite an enquiry as to the efficient cause of it; and whether that be found to have existed in the materials or the process, the experienced brewer will thence adopt a practice productive of better effects. This, however,

ever, is applicable rather to a *partial* than to a *total* setting of the goods; for an accident of the latter kind will force itself upon the attention of the most ignorant and careless, whilst there are degrees of the former which will escape the notice of the intelligent and attentive, without the means of detection here recommended.

An accident of this kind once came within our own observation, wherein, by the inattention of a servant, the goods were so far *set*, that by two mashings, adopted to produce the usual length of one, the gravity of the wort, which should have been 30 pounds per barrel, was only 11, and still the quantity was somewhat less; being 31, instead of 32 barrels; the loss, therefore, in the first extract only, may be thus estimated:

First wort should have been 32 bar. at 30 — 960
 Instead of which, it was only 31, at 11, — 341

Deficiency —

619

O 3

Which

Which being divided by 75 pounds, the average amount of the fermentable matter then extractible from a quarter of malt, and the actual loss appears to be 8.25 quarters of malt.

In a situation so alarming, without the instrument for our guide, we should have been totally at a loss how to have proceeded, or to what purpose to have converted a wort whose quality must have been unknown to us. Similar accidents, though in a less wasteful degree, we are convinced, do frequently occur and pass unnoticed, in the want of these or similar means of discovering them.

Amongst the causes of such accidents may be reckoned the use of very low ground, and very high dried malts, with improper degrees of heat in the liquor applied to them; and that of stubborn, flinty, ill-made malts, and of such as are just off the kiln, though attended with what would have been termed *proper heats*, on other occasions.

By

By the use of the saccharometer, also, we are enabled to detect that absurdity in the practice of many country brewers, which the notable dames of yore agreed to call *leaking on*, a term which means nothing more than the continued sprinkling of water upon the malt, after the tap is nearly spent, till the quantity of wort is produced which the brewer thinks will yield the required length, or quantity of beer, without any regard to the quality of the malt, or that of the wort so produced.

The least reflection, without the aid of the instrument, will point out the absurdity, though reflection alone will not inform us how much is lost by the practice; for what power, or what time, has a fluid to extract, which is sprinkled over the surface of the materials, and immediately trickles out below, without being allowed a stationary moment for infusion? And though the practice we are here condemning is confined to some

small breweries in the country, we cannot exempt the larger ones from all share of censure on the occasion; for if the *piece-liquor* of some of them is not exactly in that predicament, it verges so very nearly upon it, that we cannot pass it over without recommending the subject to the consideration of the proprietors.

Another circumstance wherein the utility of the instrument is obvious, is the being able to produce the same strength in any malt-liquor, which we are desirous should be substituted for some other, the produce of another place. If, for example, we would imitate Burton ale, Ringwood beer, or London porter, by being previously informed of the respective average gravities of the worts which produce them, we can be correct in the imitation of their strength, a particular of which we cannot be assured by any other means; and this is of the greater importance, because the
malts

malts made in one place frequently differ very much in quality from those made in another.

To exemplify this, we will suppose that a brewer of Edinburgh, being informed that the London brewery draws two barrels and a half, or two barrels and three firkins of porter from a quarter of malt, immediately set to work, and drew a length in that proportion, without considering the difference in the quality of the malt brought to the London market, and that produced in Scotland, we may readily suppose that he would find his liquor exceedingly deficient in point of strength, and himself much disappointed. On the contrary, if, being willing to make a random allowance for the supposed deficiency in the quality of the malt, he were to draw only two barrels per quarter, when perhaps it would have afforded two barrels and a firkin, he is then trading to a disadvantage, which a knowledge of the strength of London
porter,

porter, and the application of the saccharometer, would have prevented.

By means of this instrument, too, the perfect analysis of malt-liquor might, perhaps, be effected, with the view of discovering, with certainty and precision, the constituent parts of its strength; and this discovery, by an ingenious hand, might lead to further advantages.

If the gravity of a given quantity of perfectly transparent wort* were taken, and the portion of solid yeast used to ferment it were exactly weighed; by taking again the gravity, and noting the quantity of the beer, in a transparent state, having previously weighed with precision

It may not be unworthy observation, that wort in its natural state of turbidity appears less dense than when transparent; but the difference is very trivial. A wort of 49.75 pounds per barrel, in the former case, was exactly 50, when filtered through a flannel bag to perfect transparency; but not having had occasion to make any other experiments on this subject, we give it as the result of one only.

the

the quantity of yeast and lees produced from it, perhaps a clue might be taken hold of which might direct to the discovery of the analytical process we are solicitous of. The amount of the yeast and lees, added to that of the unattenuated fermentable matter, should make a sum equivalent to the sum of the yeast first used, and the amount of the fermentable matter extracted; it would then remain to be ascertained—how much fixed air had escaped during the fermentation—what portion remained enveloped in the unattenuated fermentable matter—the amount of the spirit generated—and what portion of water made up the measure of the composition.

At least, the object seems worthy the attempt of any one who may have leisure, ingenuity, and inclination enough to undertake it; and should it not answer the end proposed, the enquiry is not incurious, nor unpromising of useful information; for, as Mr. Hales has well observed,

observed, “ new experiments and discoveries do usually owe their first rise only to lucky guesses and probable conjectures; and even disappointments in these conjectures do often lead to the thing sought for.”

After what has been said upon the various, new, and useful purposes to which the saccharometer may be applied, we think it superfluous to dwell longer upon the subject; and therefore submit it to the reader to adopt or reject the use of it; as his own understanding may dictate.

At least, the object seems worthy the attempt of any one who may have leisure, ingenuity, and inclination enough to undertake it; and should it not answer the end proposed, the enquiry is not a curious, nor unpromising one. As Mr. Bates has well observed,

APPENDIX

A P P E N D I X.

*Describing the philosophical Principles upon
which the Construction of the Saccharo-
meter is founded.*

By a F R I E N D.

WHEN I transmitted you my first notions of being able to procure a more accurate and compendious mode of making the *saccharometer* than what you had proposed, I only gave you the dawn of my ideas on the subject. Having no foundation to argue upon but my own notions, I could not speak with that precision necessary for conviction. What I said then, was only to shew the propriety of your communicating to me all the information which you had collected from your experiments, in order that I might
know

know what there was a necessity for my doing, and what I might let alone : but, perceiving that you were too much engaged to talk with me at large upon the subject, and that, indeed, your experiments had not been adequate to my purpose ; being unable, also, to collect any kind of information in point from the past investigation of the philosophical world here, I found there was an absolute necessity for my going through the whole of the enquiries upon the ground of my own examination ; I was the more prompted to it, by observing, in your reply to my notions and enquiries,

First, the impossibility of vouching for the truth of a standard formed as yours had been. I do not mean so much from the rudeness of your guage and weights ; for you will find, by a comparison with what is contained in the following sheets, that in the weight of water you come near the truth ; but from that slovenly manner of forming the first standard wort, by
forty

forty distinct *fillings* of a thing made of tin, which you call a *measure*; where the error of every distinct filling, of necessity in itself important, must, when multiplied by *forty* operations, grow into an enormous size, unless that preternatural agency, called chance, was kind enough to extend its influence in the correction of one error by another.

Secondly, the appearance of a palpable error under which you labour, in the supposition of your present instrument being perfectly the same as it was before its accident *; and of which I think I can readily convince you. I will take it for granted that it was at first, with No. 30 at top, the true representative of the resistance of a wort of 30 lb. per barrel, to the

* The accident here alluded to, was a bruise in the ball of the instrument; which, in lessening the bulk of it by so much as the bruise had indented or forced the metal inwards, made a less weight necessary to sink the instrument in water to the required point on the scale.

J. R.

with

admission

admission of a body which, we will say, contains 4 cubic inches :

Express the weight of that cube by any No. 1000

Express the weight of No. 30 at top by — 100

Force exerted upon 4 cubic inches — 1100

Suppose the instrument, by a similar accident, or otherwise, to be lessened one half, and become 2 cubic inches. In order to make it float at the same point in water, you take off from the original weight one half, and it becomes — 500

Add the weight at top *unaltered* — 100

Force to be exerted, to sustain 2 cubic inches 600

But the force with which your fluid is capable of acting on a cube of 2 inches, is only 550 ; and, therefore, will require an increase of density in the relation of * 600 to 550, to support the instrument

* i. e. exactly double ; this will be equally evinced by the more direct consideration, that the same weight, added to a cube of 2 inches, and another of 4 inches, must, in the former, require double the resistance.

with

suspicion that there existed a partial fallacy in the very foundation of your system. But, even supposing it to have been accurately true, I recollected the extreme difficulty and trouble which you found in making with precision the saccharine mixture, when you were in London, the smallest addition on either side of the required medium destroying the intended standard; added to the great indecision in noting any one accurate point upon the scale, owing probably to its attraction to the surface of the fluid, I was clearly convinced that an instrument with its standard weight being given for the creation of future mixtures, by an immersion in which to ascertain the weight on the top of future instruments, would be extremely tedious in the operation, very uncertain, unless conducted by a hand which could be trusted to, and, if conducted by such a hand, expensive. It is, besides, to the last degree clumsy and unphilosophical, and such as one could hardly

ly

ly offer without a blush to a workman, who had a head capable of conducting the business, as the foundation of a new creation in the world of science.

By all these reasons, I was induced to turn my thoughts to the procuring a knowledge of the resistance which a wort, containing your proposed standard of 30 lb. per barrel, makes to the admission of a body immersed in it, compared with the resistance made to the same body by water; the difference of which being ascertained in figures, would furnish a precise, philosophical, and easy scale, upon which to form the relation between the instrument and its standard weight. This scale would have been supplied at once, provided the resistance was occasioned by the force of gravity alone, agreeably to the general axiom in hydrostatics, that *the weight of a fluid displaced is always equal to the weight of the displacing body*; for, in this case, there would have been no more to do than say, as the

weight of a barrel of water is to the weight of any barrel of wort intended to be fixed on as a standard; so is the weight of the column of water displaced (or its representative, the displacing body) to the same column of wort, the difference between which would give the weight of No. 30. But I was convinced, on reflection, that there are other principles in fluids, by which they resist the admission of a descending body, and the first of these is that of attraction, which operating powerfully on bodies composed of heterogeneous particles, must have considerable influence in such a fluid as wort. A tendency to coagulation in the higher temperatures, and an approach to congelation in the lower ones, which, perhaps, are only modifications of the first, are certainly co-operating principles in all gelatinous liquors; but, as they probably have not much influence in worts, at least in those degrees of temperature, within which you have limited the examination of practice,

I con-

I consider only the operation of the two first, and to their combined effects I give the name of * *spissitude*. It was my business then to enquire the relative amount of that spissitude between the standard wort (of 30 lb. per barrel) and the solvent principle; which being ascertained by the same weights, furnishes the unerring scale required.

In order to satisfy you clearly of the truth with which this enquiry has been conducted, and to warrant your confidence in the adoption of this accurate foundation for your future system, in preference to the imperfect one, which was all that your guage and weights had the power of furnishing you with, I shall enter into rather a minute history of my mode of conducting my course of experiments, together with some account of the apparatus with which they have been made.

I avoid the equally good appellation of density, because common use has confounded it with the idea of gravity alone.

With some interest among the ingenious world here, I procured a scale beam calculated to answer my purposes. I found it would turn well with $.03125$, or one thirty-second of a grain (even with five penny-weights on it) and so strong as to bear loading with 4 ounces troy, determinable then by 0.25 , or one-fourth of a grain. To give it the command of the latter, it was indebted to an invention of my own, to take off the vibration; which, for accuracy and dispatch, I consider as a very great improvement in the scale beam. My next thing was to *make* a set of weights accurately related to each other; finding upon examination that any which could be purchased ready made, were even more erroneous than my opinion had first suggested. By having access to a pair of assay scales, which would turn with $\frac{1}{256}$ of a grain, after a good deal of making and re-making, I completed a set of 11 weights in arithmetical progression from 1 to 1024 grains, and downwards to $.03125$, or one thirty-

thirty-second of a grain. It was not for the sake of my experiments alone, that I was at this trouble, my intention being at the same time to furnish an accurate scale for the manufactory of future instruments.

To ascertain the relative gravities of different waters, being the first object, I got a very light phial blown of as large a size as my beam was capable, at the utmost, of supporting the weight of (nearly one-third of a pint). To the neck I joined a piece of a cylindrical glass tube, about $1\frac{1}{2}$ inch long, of a convenient size to admit readily of filling and emptying the phial. I afterwards ground off the top square, and also the inside of the neck, to some degree of truth; into this I fitted, by filing, &c. a fine cork, through which a small glass tube had been inserted and cemented, drawn at a little distance above the cork to the fineness of the smallest pin-hole, and there ground off. The cork I charged full of a composition of bees-wax and tallow, and finished it by a cement at bottom in

a conical form upwards, to the aperture of the small glass tube in the middle. Around the top of the cork I cemented also a collar of wood, as a shoulder, to fit square on the top of the neck which was ground off. This phial being filled near the top, and the stopper, thus prepared, being introduced, the water, compressed by the descent of the stopper in the cylinder, escapes through the conical aperture, and the stopper being pressed with care tight to the shoulder, the water as it escapes being taken off at the small aperture of the tube, gives an ascertained volume of water*, guaged to a very great nicety indeed. As a proof of it, in the commencement of my experiments, I filled it four successive times with distilled water, without varying at any one time one-fourth of

* The quantity of water weighed being 2083 grains, and determinable then by 0.25, gives a guage to the $\frac{1}{133}$ part of the whole, equal to $\frac{1}{30}$ of a pint, or about $\frac{1}{2}$ oz. per barrel; a degree of accuracy which you could not approach, and which I am of opinion would not be easily exceeded,

a grain.

a grain. I also refer you to the agreement of the three first lines in the table of gravities, which were not set down there until ascertained by the most careful experiment. The process of each weighing was as follows: I made a weight, which in the opposite scale, served as an exact balance to the bottle and stopper, after it was rinsed out with distilled water, and drained, but not too nearly, in order that I might the more easily, by adding or taking out a small portion of a drop, bring it always on an exact equilibrium with the weight. This operation of rinsing out with distilled water and nicely adjusting, was patiently performed previous to every separate weighing: the phial was then filled in the manner above described, and from these operations is obtained the column of gravities as given in the following table:

A Table

A Table of the specific Gravities and relative Spissitudes of various Waters.

	Gravity.	Spissitude.
Water, distilled (<i>by a common still</i>)	1000.	1000.
Ditto, ——— (<i>in pure glass vessels</i>)	1000.	1000.
Snow, dissolved ———	1000.	1000.
Thames, ———	1000.3	1000.182
New River, ———	1000.3	1000.344
Chalybeate spring, <i>Islington</i> ---	1000.9	1000.889
Hare-Court pump, <i>Temple</i> ---	1001.29	1001.349
Hard spring, <i>Surrey</i> ---	1001.649	1001.664

In order to examine the spissitude, I took the only one which was fit for my purpose of the various balls *, in the attempt to execute which, with propriety, I have been incurring a considerable degree of expence on your account, and from the disappointment attending their being spoiled by various workman hitherto, I have been experiencing a much greater degree of chagrin on my own. I fitted it up with a proper weight at the bottom, and a fine hair at the top connecting it with one end of my beam, whose excel-

* Balls made for the first instruments. J. R.
lence

lence furnished me by this means with a much more delicate hydrostatic apparatus than any thing which could be procured, unless at a great expence. My mode of conducting the operation in each experiment, being that which is practised with every common apparatus of the kind, needs not be particularized to you; it is enough to say that the differences between the weight of the suspended ball in air, and its preponderation when immersed in the fluid, gave me the measure of the power exerted by that fluid in resisting the descent of the apparatus, i. e. *the amount of its spissitude*. In this manner was the column of spissitude obtained *, to a pe-

* The beam when the apparatus was immersed in water having no more than 132 gr. about 5 dw. upon it, and turning with $\frac{1}{12}$ gr. ascertains the spissitude to a much greater degree of precision than that with which the gravity has been done; for 1089, the weight of the cube in vibration, multiplied by 32, shews the power of determining the resistance of 1 in 34848.

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	Gravity.	Spissitude.
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Chalybeate spring, <i>Islington</i>	1000.9	1000.889
Hare-Court pump, <i>Temple</i>	1001.39	1001.349
Hard spring, <i>Surry</i>	1001.649	1001.664

In order to examine the spissitude, I took the only one which was fit for my purpose of the various balls *, in the attempt to execute which, with propriety, I have been incurring a considerable degree of expence on your account, and from the disappointment attending their being spoiled by various workman hitherto, I have been experiencing a much greater degree of chagrin on my own. I fitted it up with a proper weight at the bottom, and a fine hair at the top connecting it with one end of my beam, whose excel-

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rufal of which I now refer you, so far as respects the different waters †.

I had now got far enough in experiment to be able, from the *data* supplied, to know precisely, whether my notions of the necessity of this nice examination were warranted by the fact; and whether there really existed any other principles in fluids, besides that of gravity, co-operating in their resistance to a descending body. The reasoning on this is obvious: distilled water, if totally pure, I considered as a per-

† Neither the contents of the phial by which the gravity was ascertained, nor the cube of the ball immersed to find the spissitude, could be supposed to be precisely 1000; but in order to furnish a more immediate and agreeable comparison between the relations of waters, &c. I have reduced all the sums, as given by my weights, to the scale of 1000, by saying as the specification of the gravity and of the spissitude of distilled water is to 1000, so are the specifications of all the rest to the sums inserted here. This method also gives, at one cross view, the immediate comparison between the respective gravities and spissitudes, as will be alluded to presently,

fect

fect homogeneous body, whose particles have no attraction to each other: I supposed ours perfectly so, and said,—as the gravity of distilled water is to its spissitude, so will the gravity of every fluid be to its spissitude, provided there be no other co-operating principle; but recurring to the table, and examining attentively the two columns, in a comparison between the water of the Thames and of the New River, we find, in the former, a deficiency, and in the latter an excess of resistance. The same is observable in a comparison drawn between the chalybeate spring and that of Hare-Court in the Temple. I have also noticed the same phenomenon in a comparison of other fluids whose gravities were nearly alike, but whose combinations were different; from the result of all which observations, it might be amusing to the mind to lay down theories with regard to the purity or impurity of fluids, inferred from the excess

excess or deficiency of that resistance, compared with what they possess from the power of gravity alone; but it is much beside my present purpose to pursue such minute speculations; it is enough to direct to a perusal of the table, where the indication of a difference between the actual and comparative densities of fluids, in proportion, perhaps, as they consist of heterogeneous particles, shews the necessity of attending to this circumstance, in the construction of an instrument which is meant to measure the relation between a simple and a combined fluid *. It shews
evidently

* I suppose that the principle upon which the hydrometer for spirits is constructed, has been taken from the examination of gravity only; and possibly the difference between real and comparative density, in such nearly homogeneous fluids, may not be so great as to render any other scale necessary for practice, although there certainly is some difference in the examination of philosophy. What that difference is I would have enquired, but for reasons which will be given hereafter; for I believe my apparatus delicate enough to have
examined

evidently that a scale formed on their comparative densities, or, in other words, their specific gravities, must be wrong; and that one formed upon their actual spissitude or resistance, must be clearly and indubitably right.

To the formation of this scale I now proceed. And here I might have contented myself with getting your instrument here, and examining the precise relation between it and its No. 30, by my weights, &c. have given that as a scale upon which to form future instruments; for whether your No. 30, as related to your instrument, be or be not the representative of an *accurate* resistance of 30lb. of fermentable matter per barrel, is very immaterial to the purpose, so long as the amount of that resistance is divided into equal parts downwards, &c. But, as I conceived it in some degree necessary, in the formation of a new instrument,

examined it with some precision. To its sensibility I am indebted for its having conducted me thus clearly to a proof of my first suggestions.

to give it a basis which no philosophical investigation can possibly invalidate, and being clearly convinced of the imperfection of your guage and weights for the purpose, &c. as I before noted, I proceeded to enquire what the actual resistance or spissitude of a real wort, containing our addition of 30lb. per barrel was, compared with the actual resistance of water. The first thing is to know the weight of a barrel of water, which is done as follows:

	36 gallons in a barrel,
	282 cubic inches in a gallon,
Cub. inches in	10152 ditto in a bar. beer measure.
1 gal. wine meas.	
	43.948 wine gallons in ditto
	158480 grs. Troy in 1 ga. w. m.*
Value of 1lb.	
Averd. in	7000) 2570079.040 d°. in 1 bar. beer meas.
grs. Troy	
	367.154lb. Av. in 1 bar. of water
Add	30. standard incr. of gravity
	397.154lb. Averd. in 1 bar. of standard wort.

In

Your having fixed 30lb. Averdupois as the standard addition to a barrel of water, I was obliged

APPENDIX. 225

In the proportion therefore of 367.154 to 397.154 must my water be related to my wort, the comparative *spissitude* of which is to form the true relation be-

obliged to go a little about, in multiplying by inches in a barrel, beer-measure, and dividing by ditto in wine measure, in order to reduce the former into wine-gallons, that I might know its weight upon some ascertained scale, viz. grains Troy. The amount of 7310 per pint, or 58480 per gallon, being received from one of the first enquirers into fluids here. The water meant is rain-water.

The cubic inches in each are from examination of *the standards*. The number of grains Troy, per pound Averdupois, is the relation of the two weights, as lately settled by the Royal Society. It has been in estimation, varying a grain or two above and below that standard.

You make your water 369lb. per barrel. The difference I impute to the imperfection of your guage and weights; to the experiment being made in a half barrel, in which a small error *plus* becomes doubled in the multiplication; and to the circumstance of your river-water being somewhat heavier than rain; all which considered, I should not have expected you to have come so near the truth.

Q

tween

tween the instrument and its standard weight.

To ascertain this spissitude, which (from what has been said above, in the discovery of the difference between the actual and comparative densities of fluids) could only be done by examining the real fluid itself, I appealed to some minutes which I have of yours for the making of mild ale, and following the process exactly, I manufactured a very well-flavoured wort, which I found about 5 lb. per barrel heavier than the proposed standard. I reduced it afterwards with water, taking great care to make the commixtion perfect; and with much perseverance and repeated fillings and weighings of my phial, brought it exactly to the proposed standard 2253.336.

As 367.154, the weight of a barrel of water,
Is to 397.154, ditto — of wort,
So is 2083.125 weight of my phial filled with
distilled water, *
To 2253.336, ditto — filled with standard wort.

* This calculation I begin from the ground of distilled or rain-water, because it is something

The *spissitude* of which being immediately examined by the hydrostatic apparatus, and compared with that of the original principles, I obtain the first great end of my pursuits; viz. an ascertained scale for the relation between the instrument and its standard weight: for *as the spissitude of water is to the increase of spissitude, so is the weight of the saccharometer, as floating in the same water, to the addition of No. 30, at the top, to bring it to the same point in wort.* There needs not any further illustration as a proof; but, as a corresponding argument for practice, I dismounted the ball of my apparatus, adapted to it a weight at bottom, and a regularly finished scale on the top, with the notation of the point, 0, as floating in distilled water, making by this means a regular saccharometer. Upon its im-

mediate and ascertained, and because river-water, which is in most general use, comes so nearly to it (*see the Table, opposite Thames and New River*) as not to make any difference in computation.

merſion in my wort, and the addition of a weight at the top, already prepared, and now adjusted, agreeably to the accurate ſcale of proportion juſt obtained, the inſtrument floated to the nicest preciſion at the ſame point, o, on the ſcale.

To complete the proportions of the inſtrument, there remained now only to aſcertain the ſize of that part of your addition to it, the ſliding tubes, whoſe action was to counter-balance the difference of denſity in all the different waters which might come into officinal uſe in the brewery, and with the conſtant variation of which, in different ſoils and ſituations, no ſingle inſtrument hitherto offered can, otherwiſe than by accident, correſpond. Recurring to the column of ſpiſſitude in the table, I find the extent of this variation in the variety of waters which I examined to be 1.6 in 1000. The ſpring water which exhibited the greateſt variation, (after a confutation, by experiment, of imperfect notions with regard to the denſity of waters,

waters; which I had taken up from the information of my senses alone,) was procured from a chalky, gravelly soil in the county of Surry; and, from the experiment, as well as from the correspondence of the more domestic tests of *hardness*, is probably as much entitled to that characteristic as most in the kingdom. Supposing, therefore, 2 in 1000 to be the limitation of the variation in spissitude between the present water and any which may come into use in the brewery, I went to work with my hydrostatic apparatus, and, by a little artificial increase of density, I made a water which corresponded with this proportion to the greatest degree of accuracy: by a comparison of this with the fluid in its purest state, I have ascertained the size and length of the tubes, which are to compose your regulator, in proportion to the ball: I have also, by this means, calculated the cube of the scale, proportioned to the tubes, in such a manner as shall, by notations upon

Q 3

it,

it, indicate, on the first immersion in any water, the true adjustment of the regulator, to the small divisional of 1 in 10,000 increase of spissitude.

I was now furnished with every information necessary for constructing all the parts of the saccharometer; but whilst my hydrostatic apparatus was mounted, and before I threw away my wort, I thought I might as well proceed a little further, and by examining with a degree of nicety, which you will never be able to approach with the instrument itself, the difference of spissitude or apparent strength at different temperatures, furnish you with a few corrected points to recur to in the formation of the tables, which must of necessity accompany the instrument, in order to ascertain the true strength of worts under all the variations of apparent value, from 50 to 100 degrees. An examination of the standard wort at the two extremes proved to me, in direct opposition to what I had before imagined, that
the

the effects of heat are considerably more sensible in the attenuation of fluids of a greater than in those of a less density, the variation in this being 6.6, and that of distilled water only 5.1 in 1000. This unexpected appearance suggested to me the propriety of making a wort of 20 lb. per barrel, and another of 10 lb. per barrel, in order to ascertain as accurately the extent of their variation. Having formed them with as much precision as I had done the first wort, I proceeded to examine the whole three, at three equidistant degrees of temperature, viz. 50, 75, and 100; in order to note in each the gradations of spissitude, or apparent value. From the result of which examination there occurs to me a difficulty in the formation of your tables of heat, which will require much patience and perseverance to surmount. It arises from the discovery of the following phænomena.

- I. The expansion of a fluid by heat between any two given points of tem-

Q 4

perature,

perature, 50 to 100, is constantly varying with the variation of density.

II. The expansion between any two mean points, 50 to 75, and 75 to 100, is also unequal.

III. At the time that the sum of the expansion between any two given points, 50 to 100, increases in proportion to the increase of density ; in the intermediate divisions, between the two points, it varies in a very extraordinary manner ; in the first, 50 to 75, it increases (though in a different proportion from that of the whole) with the increase of density ; in the latter, 75 to 100, it decreases in an inverse ratio.

I shall be better understood by a reference to the following table ; in which from a nice examination of the sum of spissitude or resistance of various worts, at different temperatures, the progress and extent of this variation is exhibited at one view.

A com-

A comparative view of the extent of the variation of spissitude, in liquors of different densities.

	From 50 to 75 degrees.	From 75 to 100 degrees.	Total From 50 to 100 degrees.
Wort of 10 lb. per bar.	1.703	4.132	5.835
Ditto - 20	2.315	3.782	6.097
Ditto - 30	2.87	3.731	6.601

From an attentive perusal of this you will notice, that, owing to an irregular combination of this ascending and descending ratio, although the increase of expansion between any two given points in the higher temperatures, is constantly more than between two equidistant points in the lower, (compare col. 1. and 2.) yet the variation of this increase, as the fluid increases in density (*viz.* from 1.7 to 4.1 at 10 lb. per barrel, and 2.3 to 3.7 at 20 lb. per barrel, &c.) is such, as to render it utterly impossible to give any calculation from one wort which would be applicable

to another of a different value *, or to fill up the blanks between any two distant points

* A consideration of this will dissipate the remains of that regret with which, from other motives, you were induced to give up your original scheme of substituting, in the place of those tables, the addition of another sliding tube to the instrument itself, whose extension might counteract the variation of apparent value, in the ascent through the higher temperatures. You will perceive that no scale could possibly have been applied to it, which would have corresponded with such irregular gradations of expansion. It is from the clear evidence of this impossibility that I was induced to take the trouble of examining an instrument which has lately been offered for the use of the brewery, under the recommendation of a patent ; in the appendage to which, from an ignorance of, or inattention to, the phenomena above indicated, the inventor has been misled into obvious errors. I give you the detection of them at large, in case you should think it of any moment to caution any of your readers, whose curiosity may have put them in possession of that instrument, against taking up notions, with regard to your tables, from the evidence of so fallacious a scale.

* The author is induced to suppress the publication of these detections. To point out the errors arising

points by any other means than that of tedious experiment. To pursue this enquiry thus, step by step, in all the degrees of temperature from 50 to 100, and through all the gradations, from the lowest to the highest value of worts which a brewer can have occasion to examine, is a task of a very formidable nature; to undertake it, will require about half as much of resolution as its performance will of attention and patience.

It was my intention once to have attempted the pursuit of a similar enquiry with regard to spirits, for the purpose of forming the relation between an instrument and its weights, upon a comparison of the difference of spissitude between alcohol and water; thereby furnishing you

arising either from negligence or mistake, is on all occasions an invidious task, and in the present is totally unnecessary. The mode of applying his instrument is so entirely his own, that it cannot possibly receive a recommendation from the depreciation of any other. With regard to the accuracy of his Tables, he begs to refer to the test of experiment,

with

with the means of offering for the use of the distillery the completest, if not the most accurate thing of the kind that has hitherto been constructed. By the exertion of a little contrivance, the instrument, with only the few weights it has at present, should serve in the double capacity of ascertaining the process previous to the operation of the still, and of tracing the precise value of the produce up to the highest rectifications. In addition, however, to a variety of little obstacles which would occur here, in the execution of such an instrument, with a degree of accuracy as satisfactory to me as that with which the saccharometer is given, there is one which it would rest with you to surmount, and which, I think, would stagger your resolution. The necessary toil of wading through liquors, comprehending such a variety of density, in order to indicate the real from the apparent value, at the different degrees of temperature to which officinal practice might be accommodated.

Opposing

Opposing to these impediments the limitation of sale of such an instrument, in a circle so contracted as that of the distillery, compared with that in which your present one is offered; and adding the consideration that it is not from the instrument itself that you propose to reap an adequate compensation for your labours, I give up for the present our original thoughts on this subject.

Should you, however, on any future occasion, resume an intention of this nature, the same sentiments which have prompted me to fill these sheets, induce me to tell you that you may command my best services.

I shall be happy to hear that this history of my enquiries meets your approbation, and am, &c.

London,

Jan. 24, 1784.

W. D.

P O S T.

POSTSCRIPT.

Containing PROPOSITIONS for communicating the particular Application of the Saccharometer, alluded to in the first Part of this Treatise, in order to effect a saving in the Materials, from FIVE TO TEN PER CENT.

TO fix positive terms for the particular communication of the means of procuring those benefits which are to be derived from the Author's particular mode of regulating the brewing process, so far as it concerns the application of the saccharometer, does not appear eligible, nor conducive to the end proposed; which is, to deter no one, by impressing the idea of certain expence and uncertain gain, from contributing, by his own experiments, to render general a practice intended to be productive of general utility.

As

As the probable advantages of this practice are considerable, and as its discovery was the result of long application and laborious attention, the terms of communicating it ought to be liberal; but as its effects are various, according to the variety of process pursued by various brewers, a fixed sum, such as the author would chuse to accept, established as a general premium, might be excessive in some instances, and inadequate in others. The consideration, also, of certain payment, before the event of reimbursement or reward is ascertained, or rendered probable, would operate on the minds of most people as preventive of their assent to a proposition apparently hazardous and problematical, accustomed as men are to expect *value received* previous to their relinquishing its equivalent. For these reasons, the Author proposes,

- I. *To accept no premium*; but to rest his recompense upon the event of his practice.

2. In

II. In lieu of such premium, a certain specific portion of the actual saving in the consumption of malt, only, and that for a limited time, to be secured to him by articles of agreement, which are to include a clause prohibiting the communication of the practice to any other person, for a limited time, also.

In a compliance with these terms there is no possible risque; and as no additional utensils would be necessary, in a regular brewhouse, the practice may be relinquished, without incurring expence or inconvenience, by any person who may be blind enough to oppose the darkness of professional prejudice, to the light of reason and mathematical demonstration.

Further particulars may be learned by addressing the author, at his residence in HULL; but as the number of enquiries on this subject may be considerable, it is requested that all letters be *free of postage*.

* * * The

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* * The SACCHAROMETER, in a mahogany case, is sold by JOHN TROUGHTON, *Mathematical Instrument-maker, Fleet-street;* LONDON. Price *Three Guineas*, including the Book of Tables, and Directions for using the instrument.

Small POCKET THERMOMETERS to be had at the same place.

Thermometers of the size of those above mentioned, are absolutely necessary, where the brewer has none but the common large ones, used for taking the liquor in the copper, &c. which are generally too bulky to be introduced into an assay-jar; they are also equally useful for taking the heat of the wort in the coolers, as being more conveniently portable.

Country brewers may be supplied by means of their booksellers, who have correspondents in London; and it is requested that they will be as early as possible in giving their orders, because the length of time required to finish the instruments will render it necessary to give a prefer-

R

ence

ence to priority of application, in case the orders should exceed the number of instruments on hand.

It was the Author's wish, that the gentlemen of the brewery should have been accommodated with the Saccharometer at a less expence; but the difficulty of finding an artist capable of executing a work of such extreme delicacy as that of the *regulator*, wherein the piston and the tube, though both of metal, must be perfectly *air-tight*; the length of time requisite to effect so nice a piece of mechanism; and the tediousness of regulating and adjusting the weights and other parts, to that correspondent accuracy with which he was solicitous the instrument should be finished, and for which every instrument executed under the direction of Mr. Troughton is celebrated; these considerations, maturely weighed, will account for the necessity the instrument-maker was under, of fixing the price as above stated; and on a

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due reflection and comparison of this, with the price and execution of similar instruments, now in the hands of the public, it will doubtless be found but a bare compensation for superior workmanship and superior correctness.

N. B. *Each Book of Tables is numbered, correspondent to the number of the instrument with which it is given, and signed by the author, as below; in order that the purchaser may be assured of the authenticity of the former, and the accuracy of the latter.*

W. Richardson

POSTSCRIPT
due reflection and comparison of this
with the price and execution of similar in-
struments, now in the hands of the public,
it will be found that the present work is
of great value for the information and
instruction of the public.

ADVERTISEMENT.

Of the Publishers of this Treatise may also be had

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Including some Strictures on the Nature and Properties of

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The Effects of *Heat and Cold* on fer-
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